A DICTIONARY OF SCIENCE,

PRECEDED BY AN ESSAY ON THE HISTORY OF THE PHYSICAL SCIENCES.

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A

DICTIONARY OF SCIENCE;

COMPRISING

ASTRONOMY, CHEMISTRY, DYNAMICS,
ELECTRICITY, HEAT, HYDRODYNAMICS, HYDROSTATICS,
LIGHT, MAGNETISM, MECHANICS, METEOROLOGY,
PNEUMATICS, SOUND, AND STATICS;

PRECEDED BY AN ESSAY ON THE HISTORY OF THE
PHYSICAL SCIENCES.

G. F. RODWELL, F.R.A.S., F.C.S.

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LIST OF CONTRIBUTORS.

J. T. BOTTOMLEY, M.A., F.C.S., Lecturer on Natural Philosophy in the University of Glasgow, . .	Electricity, Magnetism, and Miscellaneous Articles.
WILLIAM CROOKES, F.R.S., F.C.S., .	Light and Chemistry.
FREDERICK GUTHRIE, B.A., Ph.D., Professor of Natural Philosophy in the Royal School of Mines, . .	Hydrostatics, Hydrodynamics, Pneumatics, and Sound.
R. A. PROCTOR, B.A., F.R.A.S., Late Scholar of St John's College, Cambridge, ...	Astronomy, Meteorology, and Miscellaneous Articles.
G. F. RODWELL, F.R.A.S., F.C.S., Lecturer on Natural Science at Clifton College, ...	Introductory Essay, Heat, and Miscellaneous Articles.
CHARLES TOMLINSON, F.R.S., F.C.S.,	Miscellaneous Articles, including *Nucleus*, *Solution*, *Supersaturation*, *Submersion Figures*, &c.
RICHARD WORMELL, M.A., B.Sc.,	Statics, Dynamics, Mechanics, and the Theory of Music.

"Quod si cui mortalium cordi et curæ sit, non tantum inventis hærere, atque iis uti, sed ad ulteriora penetrare; atque non disputando adversarium, sed opere Naturam vincere; denique non belle et probabiliter opinari; sed certo et ostensive scire; tales tanquam veri Scientiarum filii, nobis (si videbitur) se adjungant; ut omissis Naturæ atriis, quæ infiniti contriverunt, aditus aliquando ad interiora patefiat. Atque ut melius intelligamur, utque illud ipsum quod volumus, ex nominibus impositis magis familiariter occurrat; altera ratio sive via, anticipatio mentis: altera interpretatio Naturæ, a nobis appellari consuevit."

Novum Organum.

PREFACE.

During the last few years the condition of Physical Science in this country has been essentially changed. Concretely, science has received more ample recognition from the State, and from the Public at large, than ever before: individually, each science has progressed rapidly; discoveries have multiplied as the number of science-students has augmented; and the results of research have been disseminated by means of more complete and extensive courses of scientific instruction in our Universities and Schools. In fact, science is altogether less esoteric than it used to be: it has ceased to be the study of the chosen few, and it thus happens that the language which it adopts, is being received more and more into the language of every-day life. We must remember, however, that the facts and deductions of science accumulate very quickly, and are often of a complex and recondite character, particularly in the form in which they are first presented to the world by those who discover or elaborate them; hence they ever require to be simplified and popularised before they can enter into the general literature of a community. The secrets of Nature do not come to us in a direct manner, for the natural philosopher is *Naturæ minister et interpres*, and the interpretation of Nature is science, and the interpreters of science are scientific works. To be such is the object of the following pages, and with this in our view we have given as complete an account as the space permits, of the more strictly experimental sciences, divested as much as possible of abstruse treatment and difficult formulæ. Recent results and generalisations have been added, and each science, although scattered throughout the book, is connected and complete in itself. Ready reference has been facilitated by breaking up a subject, whenever it could be done without detriment; and frequent cross-references have been introduced, both for the maintenance of continuity, and for guiding the mind to collateral subjects.

The abstract sciences of Algebra, Geometry, &c., and the classificatory sciences of Botany, Zoology, &c., are not within the scope of this work, which is confined to—

1. Astronomy.

2. The Sciences usually included under the term Physics, viz., Statics, Dynamics, Mechanics, Hydrostatics, Hydrodynamics, Pneumatics, Sound, Light, Heat, Electricity, Magnetism, Meteorology.

3. Chemistry.

Astronomy enters the domain of the abstract sciences; Chemistry that of the classificatory sciences; the wide gap between the two is filled by Physics proper. The classificatory sciences, both inorganic and organic, will form the subject of other works in this series.

During the passage of this work through the press no scientific discoveries of importance have been made. We have, however, thought it advisable to introduce abstracts of several of the papers which were read at the Liverpool meeting of the British Association for the Advancement of Science, held in September last; together with notices of articles in various recent numbers of scientific periodicals. We therefore believe that the following pages contain a full record of the results of scientific research during the major part of the year 1870. In addition to the subject-matter given with the List of Contributors, may be mentioned various articles relating to molecular physics and theoretical chemistry, by Mr. Tomlinson and Mr. Bottomley. The Editor also desires to express his acknowledgments to Mr. W. F. Barrett, Professor Heaton, and Mr. G. T. Atkinson. The article on Musical Intervals is the joint work of Mr. Wormell and Mr. Murby. The Introductory Essay relates mainly to various subjects of interest connected with the earlier history of the sciences of which this work treats; their later history and present aspect will be found in the text itself.

G. F. RODWELL.

ON THE

HISTORY OF THE PHYSICAL SCIENCES.

It is unnecessary to give here a complete, or even very connected history of the Physical Sciences, because the succeeding pages of this work contain the principal historical data connected with the various sciences which we have there discussed. Thus, it would be a waste of space, and of the reader's time, if we were to do more than refer to the astronomical system of Copernicus, or to the principle of Archimedes, because under the headings, *Copernican System*, and *Archimedes, Principle of*, the desired information will be found. Although the facts belonging to each science are of necessity scattered throughout the work, the historical portion of the subjects will be usually found under the heading of the science, as, for example, under *Astronomy, Heat, Mechanics, Electricity, Meteorology*. We propose, therefore, to consider here certain points of historical interest which do not come within the scope of the after-part of the work,—such as the Physical Science of the Ancients, and the causes which have retarded the progress of science.

Of the Physical Science of the Ancients.

All mental action is resolvable into two distinct modes; there are possible to us two definite forms in which we can exercise our intellects. The first of these is an action of pure subjective reasoning, an action neither external to the mind, nor induced nor actuated by external causes, but essentially intrinsic, by means of which we ascertain the nature of the laws of thought, classify and analyse them, and assign special functions to them. The second is an objective action, an action induced by external causes, and by that which is capable of direct recognition by the senses. We are prepared, therefore, to find that philosophy has in all ages been divided into two distinct parts; the one having reference to the investigation of the laws of thought, and to influences unseen and incapable of direct recognition by the senses; the other relating to the investigation of nature, to the study of the material universe, the laws which govern it, and their manner of operation. The former kind of philosophy is sometimes called *Metaphysics*, the latter *Physics* (φύσις, nature).

Socrates was the first to introduce mental philosophy into Greek philosophy. His disciple Plato called the philosophy of mind "dialectics," and distinguished it from physics, as the science of the eternal and immutable, from the science of the mutable. Aristotle called the Platonic dialectics in an extended form, "the first philosophy," and physics, "the second philosophy." The term *metaphysics* did not appear in philosophy until long after the time of Aristotle; it was introduced by Andronicus of Rhodes (B.C. 58), (one of his many commentators), who prefixed the words, τὰ μετὰ τὰ φυσικά to fourteen books without title, which he found among the MSS of Aristotle. The term has been since retained in spite of its want of applicability.

Metaphysics and Physics have always been more or less connected, and at an early period, the distinction between them was less obvious than it has since been. In the first ages of philosophy, the two were closely blended; in a later age they were entirely dissevered; later again there was a slight union of the two at certain points of contact which had not before appeared. There was undoubtedly a crude form of physical philosophy coeval with the rise of mental philosophy; but the former can scarcely be said to have existed for more than two centuries. Compared with the philosophy of mind, the philosophy of matter is essentially modern. There were vast and exhaustive treatises on the one, before the other had received any development whatsoever. In the Platonic philosophy, we find the grandest development of a pure philosophy of mind, but at this time, and twenty centuries later, there was no physical system which could pretend to any degree of completeness.

The pre-Socratic philosophers made many attempts to arrive at the causes of natural phenomena, and to find an explanation in nature of the complex machinery of the universe. We observe in the earlier systems a very marked tendency to assign a first place to some one entity; a primal element, from which all others emanate. Thus Thales considered water the first element; Anaximenes, air; and Heraclitus, fire. Thales (640–550 B.C.) has been called the "first of Natural Philosophers," and by Lactantius, "the first who inquired after Natural Causes." He taught that everything is produced from water, and returns to it again, and that the earth floats upon water. He said that the soul is κινητικὸν, that is, having the power to move, and that hence rubbed amber and the loadstone have souls, because they are capable of attracting, the one light substances, the other iron. This idea of the soul of inanimate things appeared very prominently many centuries later in the writings of Jerome Cardanus and others. Again the idea that water might become earth was very generally received for more than twenty centuries after the time of Thales; among those who wrote on the subject may be mentioned Van Helmont, Boyle, Eller, Kraft, Hales, Duhamel, Stahl, Boerhaave, Margraaf, and Lavoisier. So late as 1770, Lavoisier published a paper in the *Memoirs of the French Academy*, "On the Nature of Water, and the experiments by which it has been attempted to prove the possibility of changing it into earth." In this he clearly disproved the Thalesian dogma, by showing

that if water were boiled for a length of time in a glass vessel, the earthy substance which was found at the bottom of the water did not result from the conversion of water into earth, but from the disintegration of the substance of the vessel Some went so far as to assert that water hardened by long frost becomes rock crystal Boerhaave devotes a passage in his *Elementa Chemiæ* (1732) to answering the question, "Whether water be convertible into earth," and he decides in the negative It was also believed that water by boiling was converted into air, in fact, that while some became earth, another portion of it became air. Many experiments were made with a view of proving or disproving this notion These facts show us that at a comparatively late period some of the physical ideas of the ancient philosophers were admitted

Anaximenes, a disciple of Thales, regarded air as the primal element, and considered clouds to result from the condensation of air, rain from the condensation of clouds, and hail from the condensation of rain He appears further to have regarded cold as an action of condensation, and heat as an action of rarefaction

In defining his primal element,—fire,—Heraclitus (about B C 513) to a certain extent, described the attributes of what has since been called a physical force It is, he says, perpetually undergoing transformation, but ultimately returns to its original form, it is precedent to matter, and is the motive power of the universe, and the producer of all the phenomena of nature The most perfect idea of a force influencing matter, and producing phenomena by material changes is undoubtedly to be found in the theosophy of the ancient Hindus, for Brahme personifies the actuating force of the universe, the wish, will, action, of the First Cause exercised in nature

The Pythagoreans somewhat refined the ideas of their predecessors by introducing the notion of the existence of harmony and order in the affairs of nature The Pythagorean philosophy was, however, so excessively mystical and esoteric, that it is impossible to say in what light these ideas were viewed Pythagoras (540–500 B C) is said to have first introduced mathematics into philosophy, in order to abstract the soul from corporeals, and cause it the better to contemplate and comprehend the incorporeal and eternal He also first employed the term *Philosophy* —the love of wisdom, and wisdom is the science of truth The Pythagoreans are said by some to have regarded the sun as the centre of the universe, and to have taught that from it heat and light, and indeed life, radiate into the world

Empedocles (440 B C), instead of giving prominence to some one element after the manner of many of his predecessors, admitted the existence of four elements,—earth, water, air, and fire,—which are acted upon by two forces, the one attractive, the other repulsive Thus he united the corporeal elements of former philosophers with the moving and actuating force of Heraclitus This association of force with matter is an important step in the direction of a complete physical system The four-element theory was almost universally adopted during the Middle Ages, and even so late as a century ago, it was accepted more or less widely. Thus, it

endured for twenty-three centuries. It was not finally disproved until earth, water, and air were proved by chemical analysis to be compound bodies, while fire was shown to result from intense chemical combination.

The idea that all things are composed of minute indivisible particles or atoms, seems to have originated in India long before its introduction into the philosophies of Leucippus and Democritus Kanáda, the founder of the Nyayâ System of Hindu philosophy, taught that all material substances exist first as atoms, and afterwards as aggregates of atoms At the creation the atoms fell together to produce air, then fire, a greater condensation produced water, and the greatest earth Democritus (460 B C) taught that all matter is composed of indivisible particles, which are impenetrable, and differ from each other in weight, form, and size, but not in composition The production of material forms is due to different arrangements of these atoms, which are actuated by necessity or fate (ἀνάγκη) They are invisible by reason of their smallness, indivisible by reason of their solidity, and unalterable They are infinite in number and various in form They possess an oblique motion in the vacuum, and when they fall together, by their collision and entanglement, they produce all things Democritus asserted that there is a vacuum in nature, otherwise motion of the atoms would be impossible, because there would be no place to receive them Centuries later, this question was discussed on the one side, the *Plenists* asserted that a vacuum (or space perfectly devoid of matter) was an impossibility, while, on the other, the *Vacuists* maintained that a vacuum was possible, and could be produced by artificial means Among the Vacuists were Otto von Guericke, Pascal, and Boyle, and among the Plenists, Mersennus, Hobbes, and the Cartesians Boyle (writing in 1662) describes the latter as "the subtilest and wariest champions for a plenum I have yet met with"

Anaxagoras (B C 500) to a certain extent united the tenets of preceding philosophies, and introduced a designing intelligence (νοῦς) as the governing cause of the universe, and the producer of all motion Before the creation, there was a chaos of intermingled particles of matter, which were arranged in an orderly manner by the vortical motion of the νοῦς, by which means like parts (ὁμοιομέρειαι) were brought together into one place, and aggregated into masses The νοῦς is strictly "a mover of matter," it took the place of the ἀνάγκη of Democritus, the actuating force of fire of Heraclitus, the moving force of Empedocles The ὁμοιομέρειαι to a certain extent represent the atoms of Leucippus and Democritus According to some writers, Anaxagoras was the first to introduce the idea of a rapidly moving subtle medium, or ether, as the cause of various phenomena. This idea has from the earliest ages been inseparable from Physical Philosophy, it was admitted in both the Sanch'ya and Nyaya systems of Hindu philosophy, and by various Greek philosophers, notably Aristotle, who made it a fifth element. In the present day, this notion of the ether is admitted more fully than ever before.

Socrates (*b.* 469 B C.) did not admit physical science into his system; he

asserted that it was unwise to leave those affairs which directly concern man, in order to study those which are external to him Natural phenomena are beyond the reach of man, and beyond his knowledge, hence the endless controversies concerning the first element and the manner of creation Again, even if a knowledge of the causes of natural phenomena could be gained, it would be perfectly useless, because we cannot produce them or modify them. If we knew the causes of the seasons never so well, we could not alter them As far, however, as these studies conduce directly to the advantage of mankind, they may be followed, thus, geometry applied to measuring, and astronomy in so far as it is useful to navigation, were allowed as legitimate studies by Socrates, but he deemed it idle speculation to inquire into the nature and distance of the stars The object and end of all philosophy should be a knowledge of one's self (γνῶθι σεαυτόν), all other philosophy is useless, and does not promote the welfare of the human race

In the philosophy of Plato (*b* 429 B C), we find a completion of the Socratic philosophy, and to a certain extent the union of previous philosophical systems St Augustine (*De Civitate Dei*, lib viii) says that philosophy concerns itself either with the practice of moral actions, or with the contemplation of physical causes Pythagoras had excelled in the latter, Socrates in the former, while Plato produced a complete and perfect union of the two Matter, according to Plato, is that which receives forms, as a wax tablet receives impressions, it is potentially a definite thing, just as brass is potentially a statue, because it can assume the form of the statue. "Posuerunt enim *Materiam* tanquam publicam meretricem," says Francis Bacon, in speaking of ancient philosophy, "*formas* vero tanquam procos" Plato taught that the earth is the centre of the universe, and this notion formed the basis of the astronomical system of Ptolemy, which prevailed for many succeeding centuries The shape of the earth is that of a sphere —the most perfect, the fairest and most uniform of figures, and its motion is circular, the most perfect form of motion Plato admitted the four-element theory, and classed all animate beings as creatures of fire or light, of air, of water, of earth

Aristotle (*b* 385 B C) wrote more voluminously on physical philosophy than any of his predecessors Theodorus calls him the "perfecter of physics." To the four elements of his predecessors he added a fifth,—the *quinta essentia*, or fifth essence, more divine than the others, a subtle medium in perpetual circular motion, and conferring motion upon the other elements. The earth is a sphere, and is the centre of the universe, then comes the sphere of the planets, in which he includes the sun and moon, then the heaven of fixed stars, which is near to the Moving Cause The completion of everything is the appearance in full actuality (ἐνέργεια) of all that it potentially possesses Matter and form pass into each other In his work on "Meteors," Aristotle classes comets, rain, mist, and dew, together as meteors Mist is caused by the condensation of the vapour in the air into very small drops, and the aggregation of these produce the larger drops, which constitute rain. Dew is caused by the condensation

of vapour a short distance above the earth Light is an effect produced in a thin medium, and is by it conveyed to us, sound is a motion of the air conveyed to the ear, echo is reflected sound, and light is capable of similar reflection The physical philosophy of Aristotle prevailed almost universally during the Middle Ages.

Among the ancients there was no real physical science We have record of a few detailed experiments, such as the observation of Thales, that rubbed amber attracts light bodies, the proof adduced by Anaximenes to show the materiality of air, and the notice of a few magnetic effects given by Lucretius, but these were solitary examples, and led to no result Many philosophers openly expressed their contempt for a philosophy which did not directly concern man it is possible, they said, to improve the condition of man and ennoble his mental faculties by our ethical and logical systems, why therefore should we go out of our way to study nature, whose actions and operations we can never influence? Why should we study the stars while we neglect that which is under our feet? Human philosophy was always placed before natural philosophy Diogenes Laertius says, that in philosophy we have Logic first, Ethics second, and Physics last, because the two former prepare the mind for a right contemplation of the latter, since Nature is the more divine Some have compared philosophy to an orchard full of all manner of fruit, in which Physics represents the trees, Ethics the ripe fruit, and Logic the strong fence Possidonius likens it to a living creature, of which Physics represents the blood and flesh, Logic the nerves, Ethics the soul It must be confessed that these comparisons are singularly inappropriate.

The ancients made progress in mathematical and observational sciences; thus astronomy and geometry received considerable development in their hands Astronomy undoubtedly originated in Chaldea, and it was studied by the Egyptians, the Chinese, and the Hindus, at a very early date The science passed from Egypt into Greece Thales determined the length of the solar year, and is said to have calculated eclipses Pythagoras asserted the spherical form of the earth, while Meton, or his immediate successors, invented the metonic cycle Hipparchus made a number of astronomical researches, indeed, it is wonderful that he did so much without the aid of the telescope, for he determined with some accuracy the motions of the sun and moon, and discovered the precession of the equinoxes. Ancient astronomy closes with Ptolemy, whose system was universally accepted during the Middle Ages, and until the time of Galileo

In the hands of Archimedes several sciences had their origin, among them Mechanics and Hydro-mechanics He wrote on the centre of gravity, and some of the mechanical powers and we yet find in our text-books the *Principle of Archimedes*, which affirms that when a body is immersed in a liquid it loses a portion of its weight equal to the weight of the liquid which it displaces Archimedes was followed by Ctesibius and Hero of Alexandria The invention of the force pump is ascribed to the former, while the latter reduced all machines to combinations of the five mechanical powers (Δυναμεις), a division which we still retain. In the Πνευματικα of

Hero we find an account of various machines. The elasticity of the air was well demonstrated in Hero's fountain, actuated by compressed air.

The four-element theory is undoubtedly the oldest and most enduring idea which has appeared in the whole history of science. We must be careful, however, not to confer upon it a too limited significance. The elements, fire, air, water, and earth, were not regarded in their strictly literal sense by the ancients, but rather as types of classes, and some such rude classification must of necessity exist in the early stages of physical inquiry. With *fire* they classed light, heat, flame, incandescent bodies, lightning, and all visible manifestations of electricity. With *air*, steam, smoke, and everything of an aeriform nature. All liquids were classed with the element *water*, and all solids were classed with *earth*. Thus the four ancient elements were types of great classes, which in their entirety comprehended the universe; they typified the three conditions of matter, *solidity, liquidity, gaseity*, while the *physical force* exercising itself upon matter,—the something more ethereal and divine than matter—was represented by *fire*. The ancients feigned that Prometheus had climbed to heaven and stolen fire therefrom with which he vivified mankind, and the function of fire in their physical systems is well exemplified by this story. Fire was the *soul*, while air, water, and earth, together constituted the *body*.

The ancients, we repeat, possessed no system of experimental science, nor did they ever attempt to institute or develop such a system. Nature piped unto them as she pipes unto us, but their ears were not attuned to the sounds. Yet they watched the various phenomena of the universe as we watch them, the ceaseless round of change, the ever dying of the old form, the ever production of the new. They traced the course of the stars, and created great systems of astrology in their attempts to associate mundane affairs with supra-mundane influence. They listened to the surging of the restless sea, and sought to account for its motions. They followed the sinking sun with their eyes and minds, and when the darkness came they fell down and prayed for the return of vivifying light and heat; they greeted his rising with their morning prayers, and with thanksgiving. When storms came they besought the gods of the firmament to spare their lives, and rested till the terror was overpast. They were full of awe of the powers of nature: they worshipped fearing. Their worship of nature was a true deisidaimonia.

Physical Science during the Middle Ages

Physical Science, in common with all other subjects requiring an exercise of intellectual power, made but little progress during the Middle Ages. The system of Aristotle was almost universally received, and with it the four-element theory. There was, however, one notable exception to this, for there had arisen a sect of men whose pursuits led them more or less directly to study the intimate nature of matter, and the conditions of its change under varied and forced conditions. These were the Alchemists, whose

principal object was the transmutation of the baser metals into gold, and as secondary pursuits, the discovery of an universal solvent, and of an elixir-vitæ, or elixir of perpetual life The alchemists rejected the four-element theory, and adopted three principles which they called, respectively, *Sal*, *Sulphur*, *Mercurius* These represent perfectly the four more ancient elements, but as the alchemists delighted in mystery they ignored the terms of the ancients, and introduced a parallel but more obscure series of words. The sal, sulphur, mercurius, of the alchemists, are principles, not substances, *principia* not *corpora*, the words are not to be taken in their strict sense, they are analogues, representative bodies, and, like the four elements of the ancients, they are types of great classes Under the term *sulphur*, the principle of combustibility, they included *fire*, *air* and *water* (gaseity and liquidity) are included under the term *mercury*, while *earth* is included under the term *salt*, the principle of fixity and solidity

During the Middle Ages a great mass of superstition and false science was introduced into Europe mainly from Eastern nations, and for many centuries retarded the progress of science Alchemy also came from the East, and may be classed with the other great delusions which in all countries are found at some period or other At this time arose many of the fifty-four modes of divination in which our ancestors put faith less than two centuries ago, and in some of which a not inconsiderable number of our contemporaries believe Such were astrology, necromancy, cheiromancy, and cephaleomancy Such is our modern spiritualism We have traced elsewhere the development of a mystical philosophy of the seventeenth century, in which will be found many superstitions of this nature Their effect, while it lasted, was extremely detrimental to the advance of Physical Science

There were but few writers on Physical Science during the Middle Ages Among them may be mentioned —Rhases (*b* 840), who shed great lustre on the Academy of Bagdad, which at this time was very important, and is said to have possessed observatories, laboratories, and libraries He was the author of a great number of treatises on Astronomy and Chemistry, and won for himself the title of "the Experimenter" Many of his works have never been translated, and are buried in Madrid in the library of El Escorial with so much else that would enlighten us in the matter of Middle Age lore Avicenna (*b* 980), was learned in the mathematical works of the ancients, and in the *Almagestum* of Ptolemy the astronomer, to which he added certain astronomical observations, he also wrote on alchemy and chemistry Alfonso X King of Castile (*b* 1223, *d* 1284), appears to have been a most exceptional Middle Age monarch He was devoted to astronomy, and the celebrated "Alfonsine Tables" were compiled during his reign, and under his auspices. In the eleventh century Alhazen, an Arabian mathematician, wrote a treatise on Optics, which was translated into Latin several centuries later Vitello, a Pole, commented on this work, on a treatise written in 1270, and added many optical observations of his own, among them he discussed the rainbow, and the nature of the refraction if light. Roger Bacon (*b*. 1214, *d*. 1292), was perhaps the greatest experi-

menter of his age, and one of the very few lights of science of the Middle Ages His works contain an account of various optical and chemical experiments, many of which were undoubtedly acquired from Arabic sources His most important work, the "Opus Majus," was not published till 1733, it is free from the enigmatical writing which characterises his other productions, and in it he discusses, with singular clearness and force, many points of scientific method which were afterwards developed in the Novum Organum of his great namesake Francis Bacon.

Physical Science during the Sixteenth Century.

The sixteenth century is not very notable in the history of Natural Philosophy The labours of many men who were eminent in the scientific world during the succeeding century were, however, commenced at the end of this century, and it must always be associated with the names of Copernicus and Tycho Brahe The former was born at Thorn in Prussia in 1473, and his great work on astronomy (*Astronomia Instaurata*), was published in 1543, a few days only before his death. During this century there were but ten supporters of the Copernican theory in Europe Tycho Brahe applied himself to astronomical observation, and collected together a great mass of matter, although unaided by the telescope, he made a very extensive catalogue of stars, which was published in 1602 A treatise on optics by Maurolycus of Messina appeared in 1575, which, however, scarcely added anything to the facts described by Roger Bacon many years earlier Baptista Porta, whose *Natural Magic* was published in 1589, invented the camera obscura Towards the end of the century Guido Ubaldi (*b* 1540), published a work of some importance on mechanics, and Stevinus of Bruges (*b* 1548) added to our knowledge both of mechanics and hydrostatics, Jerome Cardan and Nicolas Tartaglia also wrote on mechanics Galileo, whose name we meet with so frequently in the scientific records of the next century, was born in 1564, and before the end of the century had discovered the isochronism of the pendulum, and the laws of falling bodies The most important work on physical science which appeared in England during this period was Gilbert's *De Magnete*, the birth-place of the sciences of electricity and magnetism.

Of a Mystical Philosophy of the Seventeenth Century

During the fifteenth and sixteenth centuries several unimportant systems of Physical Philosophy arose, in all of which mystical lore, collected from various sources, was blended with Aristotelianism It will be a matter of interest to discuss in some detail one of these systems, because the progress of Physical Science was retarded to an unknown extent by these false philosophies. We have chosen for this purpose the philosophy of Robert Fludd (*b.* 1574, *d.* 1637), which was one of the last efforts of

eastern mysticism to unite itself with modern thought At the time when Fludd wrote, Galileo was making the most brilliant discoveries and laying the foundation for exact experimental investigation, while Francis Bacon was writing those noble works which have guided us in the pursuit of science to this day The philosophy of Robert Fludd is not typical of the period in which he lived, it rather typifies the thought of times long past Fludd was not a very staunch conservative, but he was far too conservative for that age of progress, in a very few respects he was ahead of his contemporaries, in some he kept pace with them, but in many he lagged far behind them He was not one of the great thinkers of his day, but he was a man of the most varied learning, and unwearied in his labours, he was called *the searcher* in that he was ever prying into the secrets of nature, and he was accounted "strangely profound in obscure matters" Brucker ("*Institutiones Historiæ Philosophicæ*") says of him, "Cum imaginationis vehementia fuerit, et Paracelsica, Cabbalistica, Magica, vetera, nova, in unum confunderet, quibus tamen haud paucos erudita, et a naturali experientia desumta admiscuit"

According to Fludd, God is the beginning, the end, and the summation of all things The act of creation is the separation of the active principle (*Voluntas Divina*) represented by light, from the passive principle (*Noluntas Divina*) represented by darkness By the interaction of these principles everything is produced The universe is composed of four worlds the archetypal world in which the Deity specially manifests himself, the angelic, inhabited by angels, who are the direct communicators of the Divine will, the stellar, containing the planets and all the heavenly bodies, and, lastly, the earth and the creatures which inhabit it These four worlds may be reduced to three—viz, the archetypal world, the macrocosm, and the microcosm, or God, the world, man The archetypal world is formed of three manifestations of the Deity represented by the three Persons of the Trinity God in this threefold character presents the image of a circle (which has ever been the symbol of perfection), "cujus centrum est in omnibus, circumferentia extra omnibus" The greater world or macrocosm (μακρὸς κοσμος) is an emanation from God, and is divided into three regions corresponding to the three Persons of the Trinity—viz, the empyrical region occupied by angels, the ethereal region or heaven of fixed stars, and the elementary region occupied by the earth. The lesser world or microcosm (μικρὸς κοσμος) is man, because he presents a counterpart of all the parts of the macrocosm The head corresponds to the empyreal heaven, the breast to the ethereal heaven, and the stomach to the elementary region The different parts of the macrocosm have representatives in the microcosm, and these correspond by the law of sympathy, and necessarily are influenced the one by the other This system of the world was revealed, according to Fludd, by the Deity to the first man, and by him transmitted to the Patriarchs and Moses The three great philosophers of antiquity—Pythagoras, Plato, and Hermes Trismegistus—adopted it from the Bible, but made many alterations in reproducing it. Aristotle, on the other hand, was not acquainted with the

sacred writings; his books are full of follies and errors, and he has been the cause of infinite heresies.

It will be noticed above that Fludd speaks of Hermes Trismegistus as one of the three greatest philosophers of antiquity; and from the frequency with which he quotes him we should be inclined to think that he is considered the greatest of the three. Hermes Trismegistus is often confounded with the Egyptian God Thoth, the inventor of numbers and letters, but they are distinct. According to Clemens Alexandrinus, Hermes was an Egyptian, and the author of forty-two books which his countrymen treated with the most profound respect, and were wont to carry in their religious processions. Thirty-six of these (including four on astrology) contained all the philosophy of Egypt, while the remaining six treated of medicine, anatomy, and the cure of diseases. In the temple of Hermes at Pselcis he is represented with a staff having a snake turned round it, from which emblem the Caduceus of Mercury may have been derived. Some make Hermes a priest and philosopher, who lived a little after the time of Moses; others, a contemporary of Osiris. However all this may be, it is certain that several books appeared during the Middle Ages which claimed Hermes Trismegistus as their author, and it is equally certain that they were written by Neo-Platonists and Gnostics during the early centuries of the Christian Era. Fludd has drawn largely upon the supposed works of Hermes; his cosmogony is nearly the same as that of Hermes, and much of the supernatural machinery which he introduces is derived from the same source. From this cause the philosophy of Fludd is strongly tinctured with Neo-Platonism.

We are inclined to regard as Fludd's principal work, the *Historia Macrocosmi*, which was published at Oppenheim in 1617 and 1618, and which we will consider somewhat in detail. It is entitled, "*Utriusque Cosmi majoris scilicet et minoris metaphysica, physica, atque technica historia*," and is in the form of a closely-printed folio full of copper-plates. It is dedicated to God, as was not uncommon at a somewhat earlier period—"Deo optimo maximo, Creatori meo, incomprehensibili, sit gloria, laus, honor, benedictio, et victoria triumphalis, in secula seculorum. Amen." Then follows a dedication to James I. in language which must have been rather too laudatory even for that vainest of monarchs. After this we have one of the large emblematical designs in which mystical writers took so much delight; a design in which the earth forms the centre of a circle, while cherubim and all the host of heaven form the circumference. Immediately around the earth we observe three circles within which appear respectively typical products of the animal, vegetable, and mineral kingdoms as adapted by art to the uses of mankind; a fourth circle contains types of the liberal arts, a fifth of the mineral kingdom, a sixth of the vegetable kingdom, a seventh of the animal kingdom. The eighth circle represents the sphere of air, the ninth that of fire, the tenth to the sixteenth the circles of the Moon, Mercury, Venus, the Sun, Mars, Jupiter, and Saturn. The seventeenth circle encloses a quantity of stars, and is called *Cœlum Stellarum*, and the three outer circles are fringed with tongues of

flame and contain cherubim and seraphim. At the limit of the outermost circle the hand of God is seen projecting from a cloud, and leading by a chain, Nature, personated by a human form bearing the sun and moon, and girt with stars, while from her hand depends a chain by which she leads an ape seated upon the earth The ape personates Art, for Fludd elsewhere says, "*Natura, et ejus simia quam artem appellamus*" It can well be understood, in reference to this emblematical figure, that although the world is not more than an inch in diameter the whole figure terminated by the circle of cherubim extends over more than a foot It is in good truth a wonderful mass of uncouth symbolism, and many such are found in the writings of Fludd and of the mystics of his school After the symbolic design, the work begins in good earnest with an account of the creation, and of the construction of the macrocosm, the nature of the empyrean, and the form of the elements The third book (or *chapter*, as we should call it now-a-days), *De Musica Mundana*, is essentially Pythagorean in character, in it Fludd endeavours to prove that unity and rhythm prevail in all things, and we may be sure a chapter on the music of the spheres is introduced. Book IV treats "of the creatures of the Empyrean," and in this the nature of demons is fully discussed In the paragraph relating to bad demons we find such sentences as the following —"Accusing and calumniating demons occupy the eighth mansion, whose prince is called Ashtaroth, who, active and filled with joy, exaggerates our sins before God"

Book V treats "of the creatures of the ethereal heavens," and we find herein Fludd's ideas regarding the origin of the sun, and the cause of the "circular movement of the heavens," as the apparent motion of the sun was then called He also devotes some space to the refutation of the Copernican theory, which had a few years before been adopted by Gilbert of Colchester (of "De Magnete" fame), to his honour The remarks which follow in the next chapters about thunder and lightning and meteors, appear to be taken from Lucretius and Pliny, and certainly lack any originality. The second part of the *Historia* is devoted to a technical history of the macrocosm, which is considered in the following order —"Of Universal Arithmetic," 153 pp , "Of Music," 100 pp , "Of Geometry," 31 pp.; "Of Optics," 23 pp ; "Of the Art of Drawing," 24 pp , "Of the Military Art," 89 pp , "Of Motion," 68 pp. (containing an account of various machines and pieces of mechanism, in the designing of which Fludd was said to be proficient), "Of Time," 25 pp ; "Of Cosmography," 28 pp ; "Of Astrology," 156 pp , and "Of Geomancy," 73 pp Note the significancy of the extent of the two last-named subjects Taking the whole work of more than 900 folio pages, we find nearly *one-sixth* of the space given to astrology; or, taking together the astrology and geomancy (divination by figures drawn on the earth, γῆ μαντεία), nearly *one-fourth* of the work is thus occupied. In round numbers, one-fifth of the work is devoted to the physical and metaphysical history of the macrocosm, and four-fifths to its technical history, and, of the latter branch, about one-ninth of the work is occupied by music, one-eleventh by military matters, about one-sixth by arithmetic, and one-fortieth by optics.

The other writings of Fludd, although numerous, need occupy but little of our attention In 1619 the complement of the "Historia Macrocosmi" was published at Oppenheim, under the title of "Tomus Secundus de supernaturali, naturali, præternaturali, et contranaturali microcosmi historia, in tractatus tres distribua" In this work we find at the commencement an *oratio gratulabunda*, of considerable length, addressed to the Deity, and much occupied by quotations from the Psalms and from Hermes Trismegistus It rises here and there to a certain tone approaching sublimity Among the last works which Fludd published were three large folios entitled "Medecina Catholica, seu mysticum artis medicandi sacrarium" These were published in Frankfort in 1629-30 and -31, and the motto of the books is *Non est vivere sed valere, vita* In this work, more perhaps than in any other, does Fludd employ hieroglyphics, such as the astrologers delighted in We not unfrequently find sentences which consist of two-thirds symbols, and one-third words, and the latter are often much contracted At the beginning of the first volume of the "Medecina Catholica" (which is dedicated to the then Archbishop of Canterbury), there is another of the emblematical figures of which Fludd was so fond. In it a healthy man ("homo sanus") is seen kneeling in the midst of a kind of citadel, the four corners of which are guarded by Raphael, Uriel, Michael, and Gabriel, each with a drawn sword From the north is let loose upon him the demon Maharael, riding upon a gigantic frog, and poising an arrow aloft in his hand, from the south appears Azazel, a demon riding upon a dragon, from the east, Sammael (the messenger of death), astride upon a winged dragon, and holding a torch in his hands; while from the west comes Azael, riding upon a dolphin The first volume contains a great collection of medical facts, but as we pass on to the second and third, the matter becomes weaker and weaker until it culminates in the most arrant puerility In the chapter "De nomandia sive onomantia," rules are given in great detail for finding out the priority of death in the case of two relations, and some of these rules are as arbitrary as, and somewhat of the nature of, the divination we practise when we count our cherry stones, and say, "This year, next year, sometime, never" Again, what shall we say to 93 pages devoted to divination by feeling the pulse under different planetary conditions? But the crowning point of folly and superstition remains Will it be credited that any man, much less a man of Fludd's capability, could devote 180 folio pages to "*Ouromantia* hoc est divinatio per—ουρον?" Imagine a vast system of vaticination, based upon the observation of ουρον, under various stellar and other conditions Can anything be more infinitely pitiful than this? Did any act attributed to the Laputan philosophers exceed this for folly?

It is of course impossible here to attempt any detailed analysis of the authorship of the prominent tenets of Fludd's philosophy His cosmogony is closely related to that described as Chaldæan in the writings of Psellus, Sextus Empiricus, Porphyry, Jamblichus, and Proclus, and in the works of the same period which bear the name of Hermes Trismegistus. His astrology is mainly compiled from middle age works

on the subject, which are themselves based on Arabic works, the various views of the Rosicrucians also find expression. His *Iatro-mathematics* is obviously taken from one of the works attributed to Hermes Trismegistus, under whose name was published, in 1532, a treatise entitled Ιατρομαθηματικα η παρα κατακλισεως νοσουντων προγνωστικα εκ τῆς μαθηματικῆς επιστημης. His anatomy is taken mainly from Vesalius, and his medicine from Paracelsus and his followers, but it is probable that a careful and unwearied observer like Fludd added a good deal of new matter in this direction, since it was the subject of his profession. His geometry comes mainly from Euclid, music from Guido of Arezzo, optics apparently chiefly from Baptista Porta, but undoubtedly also from Vitello, and from various Arabic sources. Fludd was neither a Copernican nor an Aristotelian, nor does he appear to have been impressed by any of the discoveries which were being made around him by Gilbert and Galileo, or by the writings of Bacon. As to his natural science, he not unfrequently shows considerable aptitude for such studies, and great minuteness of observation. Of the old experiment, in which a candle is burned in a closed vessel standing over water, which latter, on the extinction of the flame, ascends somewhat into the vessel, he says —"*Aer enim nutrit ignem, et nutriendo consumitur*," but he denied the possibility of a vacuum. Again, in the "Anatomiæ Amphitheatrum," we find a chapter entitled "*De anatomia sanguinis humani chimica artificiali dissecti*," this he recommends to be done by submitting the blood to a gradually increasing degree of heat in a retort, and collecting the products at various stages, in other words, a "fractional distillation," of necessity rough, for thermometers were then unknown. As to Fludd's astrology, perhaps the most rational thing to which he attempts to apply it is the prognostication of tempests, but the casting of horoscopes is a favourite subject, and one part treats of the discovery of a thief. "The truth of this portion of the science," he says, "is not alone supplied by others, for I also have confirmed it by practice and experience," he then tells us how to discover who the thief is, "if the Lord of the Sixth House is found in the Second House, or in company with the Lord of the Second House, the thief is one of the family, either parent, or brother, or sister," and so on. Then we have no less than *eighteen* rules to enable us to discover the form of the thief. If Mercury is in the sign of the Scorpion, he will be bald, while another planetary condition gives him height, and crisp yellow hair, some signs show him to be stout, others a monster of a deformed body, others strong and patient, while Saturn or Mars, in certain positions, show that he is bloodthirsty, and about to perish by a violent death, which at once relieves the astrologer from further anxiety, except as to his stolen goods. And this was dignified by the name of *judicial astrology*, and called an *art!* Enough has been said, we think, to show how utterly trivial were many of the applications of this rankly superstitious practice, at the same time, it is impossible for us, in the present day, to fully realise the extent of the belief in the influence of supernatural causes in the time of Fludd. It was, in every way, a superstitious age; let us remember that the belief in

witches and demons, spells, conjurations, philtres, and raisings of the devil, was as firm then amongst all classes of society as it is now in many a lone hamlet of Cornwall, many a green village of Galway, or of Wales

A word, in conclusion, as to the general character of the philosophy of Fludd Eminently a syncretist, he endeavoured to unite the dominant tenets of many and diverse philosophies by means of a cement furnished by his own active and comprehensive intellect His philosophy is tinctured with somewhat of almost every system which had gone before The basis of his system is sunk deep in Eastern soil, the summit is obscured by mists of Middle Age origin Chaldaic astrology and divination, Arabic geomancy and magic, the theurgy and theosopy of the Neo-Platonists, the aphorisms and tenets of the supposed Hermes Trismegistus, with the paraphrases of Cornelius Agrippa, the traditions and the dreams of the Kabbalists and Talmudists, Alchemical and Paracelsian visions and dogmas, and a spice of the learning of the ancient Greeks, let all these be united, with much show of relevancy, by an indubitably fertile and astute intellect, and let the whole be pervaded by a strong undercurrent of Christian tenets, and you have the philosophy of Robert Fludd A philosophy which is utterly undefinable, a wondrous blending of the ancient thought of the Eastern world with the modern thought of the Western world, a union of Christian with barbaric lore, of the wisdom of the ancients and the reveries of the East, with the unfledged crudities of the Renaissance A mixture of infinitely grand ideas, with the wildest vagaries ever conceived by the mind of man, reverential here, almost blasphemous there, pantheistic and materialistic, sublime in one place, ridiculous in another A philosophy in which wisdom and folly are seated at the same table, while Fludd acts as their host, and endeavours to reconcile them, a philosophy based on supra-mundane influence, all symbolical, all theosophical, all occult, in which an assumed influence becomes the arbiter of destinies, and the philosopher himself a thaumaturgus

Such a philosophy could not exist in the face of the great intellectual movement which, in regard to all matters of philosophy and science, glorified the seventeenth century It could not endure side by side with the works of Bacon and Galileo, of Descartes, Pascal, Hobbes, Boyle, and of the many great thinkers which distinguished this epoch With it perished a great mass of mystic lore The philosophy of Robert Fludd was as a lurid flame upon an altar, hidden in the recesses of a darksome cave, the abode of demons and unearthly forms, the philosophy of his contemporary, Francis Bacon, was as a pure light set upon an eminence, which, like the diamond in the old story, diffused its luminous influence far and wide It still diffuses it, while the altar has been overthrown, the cave is desolate, and the lurid flame has died out for ever.

Physical Science during the Seventeenth Century.

At the same time that this curious mass of false philosophy was given to the world, Galileo was engaged in the application of the telescope. Galileo was born in 1564, and at the age of seventeen was sent to study medicine at the University of Pisa During his residence at Pisa he discovered the isochronism of the pendulum In 1586 he wrote an Essay on the Hydrostatic Balance, which, however, was not published till 1615. In 1588 his work on the Centre of Gravity of Bodies was written, and in the following year he became professor of mathematics at Pisa, and made his celebrated experiments on falling bodies during the three following years In 1609 Galileo invented the telescope, and in the following year discovered the satellites of Jupiter, Saturn's Ring, and the phases of Venus In March 1611 he detected the solar spots His important "Dialogue on the Ptolemaic and Copernican Systems" was published in 1632, the general results of the publication of this work, are too well known to need any discussion here The seventeenth century was altogether so brilliant in scientific discovery, that it may safely be said that no former or succeeding century has given birth to so many results Neither in any single century have there been such a multitude of great scientific men —Francis Bacon, Galileo, Torricelli, Pascal, Boyle, Huyghens, Hooke, Descartes, Newton, Halley, Mariotte, Gassendi, Wren, Wallis, Otto von Guericke, Sturm, and Mayow, all belong to this period

The century is further notable for the establishment of scientific societies The first scientific society was established in the middle of the fifteenth century, and was called the "Academy of the Secrets of Nature" It consisted solely of men who had made some discovery in physical science From the name of the society it came to be believed that magic, and illicit arts were practised at the meetings of the members, and it was dissolved by P Paul III The Accademia del Cimento was founded in 1657 in Florence by Duke Leopold of Tuscany It was the first scientific society of importance, and had for its object the trial of experiments, to the exclusion of theoretical matter It unfortunately lasted only ten years, but during that time a number of important experiments (chiefly relating to pneumatics) were made, and the academy has left us a volume of "Natural Experiments," which is of much interest even in the present day, and has been more than once reprinted .The Royal Society of London was founded in 1660, and the Academie des Sciences of Paris in 1666

The discoveries of this century, and of the succeeding and present periods, will be found in the following pages, and we may here end our brief and somewhat desultory survey of the science of earlier ages The investigations of the natural philosophers of the seventeenth century, form in many instances the basis of the several sciences discussed hereafter; and we recognise several of the names mentioned above, even in

the direct form of headings to articles, such as "*Boyle's Law*," "*Newton's Rings*," &c.

It may be interesting, in concluding this section, to glance at the two first complete text-books of experimental science which appeared in Europe They were published during the first half of the eighteenth century, and were both written by Leyden professors. The first is the *Physices Elementa Mathematica Experimentis Confirmata* of G J s'Gravesande, the second the *Elementa Chemiæ* of Hermann Boerhaave · The former was published in 1720, and in 1742 had reached a third edition ("duplo auctior") It consists of two quarto volumes containing 1073 pages, and 127 full-page plates The following amounts of space are given to the various sciences.—statics and dynamics, 399 pages; hydrostatics, 47, hydrodynamics, 121, pneumatics, 57, acoustics, 24, heat, 31, electricity, 14, light, 228, and astronomy, 140 pages The plates are admirable, and clearly indicate that the apparatus of the period was of a very elaborate character. The *Elementa Chemiæ* was published in 1732, and was by far the most extensive and complete work on chemistry which had, up to that time, appeared It is divided into "The History of Chemistry," "The Theory of Chemistry," "The Processes or Operations of the Art" In that portion of the work, to which the general title of theory of chemistry is given, we find as full an account as was then possible of the metals, of salts, of acids, of fire, water, air, earth, of various solvents, &c Thus the first two great scientific text-books were the work of Leyden professors, and the University soon acquired such renown that students flocked to it from all parts of Europe From the time of its foundation it has been one of the principal homes of science, and a number of important discoveries have been made by its members Niebuhr has well remarked that perhaps no locality in Europe is so memorable in the history of physical science as Leyden.

Of the Age of the various Physical Sciences.

Astronomy is undoubtedly the most ancient of the sciences An observational must ever precede an experimental science, and when, as in this case, observation is stimulated by the beauty and ever-presence of the objects of study, and by the desire to comprehend the nature of the mysterious and the unknown, we can quite understand why the contemplation of the heavenly bodies should specially recommend itself to mankind in the earliest ages. The worship of the sun was one of the first forms of religion, and he was probably originally worshipped as an emblem of the great First Cause, and afterwards as himself a deity Then fire became the symbol of the deity, and later (as has often happened in the history of faiths) the symbolism was forgotten, and the fire itself became the god. The influence of the sun upon our life, and upon all the actions which take place in and around the earth, is so obvious to the most unreasoning man, that we are not surprised to find Agni the Sun—the God of Light and Fire—placed first in the Hindu Trinity. That the attendants of this

finite in their capability of observation; that they are devoted solely to the well-being of the organism of which they form a part, and hence require careful usage when applied to the investigation of the external world. He must therefore examine an experiment with extreme scrupulosity before he admits it as absolute; his mind must be fortified by legitimate modes of operation suitable for such studies; and every influencing cause must be eliminated before the commencement of a precise deduction. He may use theory for marshalling troops of experimental results, but it is to be remembered that a bad general may cause the best soldiers to lose a battle. The true student of science is penetrated by an intense desire for truth, by a fervid spirit of inquiry. He knows not whither he is going, but he sees before him, dimly and in the distance, a clear and divine light—the "lumen siccum ac purum notiorum verarum." To attain this he directs all his efforts, devotes all his life. The search for it induces the Astronomer to "outwatch the Bear," to pass a lifetime in tracking stars through the boundless space; and the Physicist to devise exquisite tortures to bend stubborn matter to his will, and compel it to disclose its inmost secrets.

The tendency of the earlier systems of physical philosophy was to supernaturalise natural actions; the tendency of modern physical philosophy is to force into the phenomenal world that which must ever be ultra-phenomenal.

The older writers on Physical Science delighted in symbolical designs, in which the forces of Nature were represented each at his appointed work, and above all they placed a cloud, from which issued the hand of God directing the several agents of the universe, and introducing harmony into their various actions. Thus, too, the true son of science, while he is filled with awe and wonder at the glory and the immensity of creation, should ever bethink him of the great First Cause.

G. F. RODWELL

A
DICTIONARY OF SCIENCE.

ABERRATION (*Ab*, from, and *erro*, to wander) A term employed in optics to designate the unequal deviation of rays of light when refracted by a lens, or reflected from a concave mirror There are two kinds of aberration, viz, *Chromatic Aberration*, (χρῶμα, colour), or aberration of refrangibility, and *Spherical Aberration* There is also in astronomy the *Aberration of the celestial bodies*, commonly (but less correctly) termed the *Aberration of light*

ABERRATION, CHROMATIC, or, *Aberration of refrangibility* A convex lens may be regarded as a number of prisms having their bases in contact Hence, when a sheaf of rays of white light passes through it, the rays not only undergo refraction, but also decomposition, and since the variously coloured rays into which white light is split up by a prism, possess different refrangibilities, it follows that when light is converged by a convex lens it is refracted to different foci The violet rays, being the most refrangible, form a focus nearest to the lens, while the red rays, being the least refrangible, form a focus furthest from the lens Thus in place of one focus there are, in reality, an almost infinite number, viz, one for each of the differently refracted rays, and in the order of violet, indigo, blue, green, yellow, orange, red Hence the rays do not meet at the same focus of the lens, and this deviation of the foci is called the *chromatic aberration* of a lens See also *Dispersion*

ABERRATION OF THE CELESTIAL BODIES, commonly (but less correctly) termed the *Aberration of Light* In astronomy, an apparent displacement of a celestial object, due to the progressive motion of light Aberration is caused in two ways—first by the orbital motion of the earth, and, secondly, by the motion of the observed celestial objects

Aberration of the former kind was first recognised by Molyneux and Bradley, and first interpreted by the latter astronomer In 1725 these astronomers commenced a series of observations of the star γ Draconis for the purpose of detecting signs of an apparent displacement due to the earth's orbital motion They presently began to recognise a displacement different in character from that which they were searching for, and further remarkable on account of its extent They found that in March the star was no less than a third of a minute of arc, south of its mean place, and in September as far to the north After several fruitless attempts to solve the meaning of this peculiarity, Bradley began a series of independent researches upon other stars He recognised before long this general rule, that each star is most displaced towards the north when it crosses the meridian at about six o'clock in the evening, and most displaced towards the south when it crosses the meridian at about six o'clock in the morning The explanation of this phenomenon remained for some time unrecognised by Bradley But he noticed, one day, while in a small vessel which was sailing up and down a sheet of water, that a vane at the mast-head constantly varied in its indications as the ship changed her course He presently recognised the cause of this, in the circumstance that the motion of the ship on one or another course affected the direction from which the wind seemed to blow, causing the wind, in fact, to seem always to come from a point nearer that towards which the ship was steering than was actually the case He was thus led to associate the phenomenon with that which he had observed among the stars Regarding the earth as in a sense resembling the moving vessel, and the light from the stars as comparable with the wind, he reasoned that if only the earth's motion bears an appreciable relation to the velocity of light, we ought to expect that the rays from a star would seem to come from a point nearer than is actually the case to that point on the heavens towards which the earth's course is directed The phenomenon he had observed corresponded exactly with this explanation The change of place due to the velocity of light estimated from the eclipses of Jupiter's satellites, corresponded within the limits of observational error, with the observed changes in the apparent positions of the fixed stars.

It follows from a consideration of the earth's path that each star appears to describe a small ellipse about its true place. This fact is of great importance in its direct bearing on observational astronomy, but it is perhaps even more important on account of the evidence it supplies as to the motion of the earth. Every star becomes an independent witness of the truth of the Copernican theory.

Since the aberration of the celestial bodies depends on the ratio between the velocity of light and of the earth's motion, its effects only vary according to the position of the observed object, not according to the distance or motions of that object. The moon is the only celestial body which is not affected by this form of aberration.

The maximum effect of aberration, or as it is called, the *constant of aberration*, is a displacement by about 20⅓ seconds of arc. This is the displacement of a celestial object when the earth's motion takes place in a direction at right angles to the line of sight. As the earth must twice in the year move at right angles to the line of sight to any star, however that star be placed, every star, twice in the year, exhibits a displacement by this amount. A star at the pole of the ecliptic exhibits this displacement at all times, and thus appears to describe a small circle around its true place. A star on the ecliptic appears twice in the year in its true place, viz., when the earth is moving exactly from or towards it. Such a star appears to travel backwards and forwards along a straight line 40⅔ seconds in length. All other stars appear to describe ellipses having a major axis of this length.

Aberration of the second class depends on the distances and motions of the observed objects. We see each celestial object not as it is at the moment, but as it was when the light by which we see it first set out. Thus we see the moon at any moment in the position she really occupied 1¼ seconds before, and we see a fixed star in the position it really occupied several years before. In the one instance there is a small displacement, in the other it is one which (though apparently small) must be estimated in reality by hundreds of millions of miles. Between these limits lie the displacements of the planets. The sun alone is unaffected by this sort of aberration.

There is a small apparent displacement of all celestial objects due to the earth's rotation on her axis. It is called the *diurnal aberration*.

There is an aberration of the fixed stars due to the sun's proper motion in space, since this motion bears an appreciable relation to the velocity of light. Sir John Herschel has pointed out that by observing the gradual change of this form of aberration (which, while constant, is wholly undistinguishable), it may one day be possible not only to supply a new proof of the sun's proper motion, but to determine the shape of the orbit in which the sun is travelling.

ABERRATION, SPHERICAL. Lenses and mirrors are usually ground with spherical surfaces, and so long as the aperture does not exceed 8 or 10 degrees, the rays of homogeneous light refracted or reflected by different parts of them meet practically at the same focus of the lens or mirror. But as the aperture of a spherical mirror increases, the rays reflected from the edges cross each other at a point on the axis nearer to the mirror than those which are reflected from portions of the mirror near its centre. Thus the rays are deviated from the true focus of the mirror. Again, with regard to spherical lenses of large aperture, the rays which pass through the lens, near its circumference, are refracted to a point nearer to the lens than those which pass through its central portion. In the case of mirrors this deviation of light from the focus is called *spherical aberration by reflection*, while in the case of lenses it is called *spherical aberration by refraction*. It may be remedied by giving lenses and mirrors parabolic surfaces, a plan which is almost invariably followed in the construction of specula for astronomical purposes.

ABSINTHIN. The bitter principle of wormwood (*Artemisia absinthium*), Formula $C_{16}H_{22}O_5$. It forms a hard crystalline mass, having an extremely bitter taste; it is very soluble in alcohol, and but slightly so in water.

ABSOLUTE BRIGHTNESS. An expression used by astronomers to distinguish between the total amount of light received from a celestial body and the intrinsic lustre of the body's surface. Thus the absolute brightness of Jupiter would be spoken of as nearly equalling that of Venus and surpassing that of Sirius, though the intrinsic brilliancy of Jupiter's light is far less than that of Venus, and not comparable with the sun-like intrinsic brilliancy of the light of Sirius.

ABSOLUTE PHOTOMETER. See *Photometry*.

ABSOLUTE TEMPERATURES (*Absolutus*, perfect, complete). Temperatures taken from the absolute zero of temperature are termed absolute temperatures, and are obtained by adding 458 to the temperature on the Fahrenheit scale, and 273 to the temperature on the Centigrade scale.

ABSOLUTE ZERO OF TEMPERATURE. When gases are heated they expand $\frac{1}{460}$th of their volume for one degree Fahrenheit, and $\frac{1}{273}$rd of their volume for one degree Centigrade

at zero It has been surmised by many physicists—among them Clerk Maxwell, and Clausius—that as heat increases the elasticity of gases, it actually produces that elasticity, that, in a word, it is the motion we call heat, associated with the molecules of a gas, which causes the gas to exert pressure, and as the molecules vibrate backwards and forwards, striking the sides of the containing envelope, they produce pressure, which increases with the increase of their own motion by additional increments of heat The absolute zero of temperature is the absolute zero of gaseous tension, at which a gas, if it could then exist as such, would possess no elastic force, exert no pressure, have no molecular motion whatsoever As 1° C of heat added, increases the elasticity of a gas by $\frac{1}{273}$rd of its volume, and each degree C abstracted diminishes the volume by $\frac{1}{273}$, it is obvious that if the law be true at all temperatures, at $-273°$ C no further contraction is possible, and hence no more heat could be abstracted, in fact, the volume of a gas would cease to exist Hence, if we could continue to withdraw heat until we reached 273° C (or 490° F) below the freezing temperature of water, we should arrive at the absolute zero, at which matter would be lifeless and inert, and incapable of responding to, or assimilating, any form of motion which, under other conditions, would influence its molecules We have never been able to produce a degree of cold approaching the absolute zero of gaseous tension See also *Temperature*

ABSORPTION OF COLOUR See *Colour, Absorption of*

ABSORPTION, ELECTIVE See *Elective Absorption of Light*

ABSORPTION OF GASES BY SOLIDS AND LIQUIDS See *Gases, Absorption of*

ABSORPTION OF HEAT (*Ab*, from, *sorbeo*, to suck in) In the seventeenth century Mariotte and Hooke discovered that glass absorbs a certain amount of radiant heat M de la Roche, in 1812, found that radiant heat, which has passed through glass, has lost the rays which glass most readily intercepts, and that as the temperature of the radiating source rises, the heat emitted passes through glass with greater facility Nobili and Melloni worked together on the subject of radiant heat The former invented the thermopile, while the latter adapted it for purposes of investigation, and made the important discovery that rock salt scarcely exercises any absorptive power upon any kind of heat His results were published in a treatise entitled, "La Thermochrose, ou la Coloration Calorifique," which has formed the basis of exact investigations connected with radiant heat Under the heading, *Diathermancy*, we have given a table of some of Melloni's results, which shows the transmission of radiant heat by certain solids The absorption is given by subtracting the transmission from 100 A *selective absorption* is exercised by bodies for heat, that is to say, certain heat rays are absorbed while others are transmitted, certain substances absorb nearly all the heat which falls upon them, and others, like rock-salt, absorb scarcely any In the case of liquids the variation is nearly as great as in that of solids thus, according to Melloni, bisulphide of carbon transmits 63 per cent of the heat of an Argand burner, while olive oil transmits 30 per cent, and water 11 Bodies which absorb radiant heat actually stop the heat waves, and assimilate the motion which they convey, thus the temperature of the absorbing body is raised

In examining the absorption of heat by liquids, Melloni employed an Argand lamp, with a glass chimney, as a source of heat, and placed the liquids to be examined in glass cells But glass absorbs a great number of heat rays, particularly of those emitted by a non luminous source, hence Melloni's results cannot be considered accurate Tyndall, in repeating some of these experiments, employed cells of rock salt to contain the liquids, and a spiral of platinum wire raised to a red heat by an electric current as the source of heat The following are some of his results, with different thicknesses of various liquids —

ABSORPTION OF HEAT BY LIQUIDS (*Tyndall*)

NAMES OF LIQUIDS	THICKNESS OF LIQUIDS IN PARTS OF AN INCH				
	0.02	0.04	0.07	0.14	0.27
Bisulphide of Carbon,	5.5	8.4	12.5	15.2	17.3
Chloroform,	16.6	25.0	35.0	40.0	44.8
Iodide of Methyl,	36.1	46.5	53.2	65.2	68.6
Iodide of Ethyl,	38.2	50.7	59.0	69.0	71.5
Benzol,	43.4	55.7	62.5	71.5	73.6
Amylene,	58.3	65.2	73.6	77.7	82.3
Sulphuric Ether,	63.3	73.5	76.1	78.6	85.2
Acetic Ether,		74.0	78.0	82.0	86.1
Formic Ether,	65.2	76.3	79.0	84.0	87.0
Alcohol,	67.3	78.6	83.6	85.3	89.1
Water,	80.7	86.1	88.8	91.0	91.0

These numbers express the per-centage of absorbed rays, thus, a layer of bisulphide of carbon of 0 14 inch thickness absorbs 15 2, and transmits 84 8 of every 100 incident rays, while benzol, in a layer of the same thickness, absorbs 71 5, and transmits 28 5 per cent Water is seen to absorb more heat than any substance in the table The absorption of heat by the vapours of these same liquids was next tried, and the order of absorption was found to be the same when the source of heat was the same, and the quantity of matter in each condition equal "We may," writes Tyndall, "safely infer that the position of a vapour, as an absorber or radiator, is determined by that of the liquid from which it is derived"

Until recently, it was believed that gases and vapours exercise no absorptive power upon radiant heat It was thought, as the molecules which compose matter in the gaseous condition are so infinitely further apart than those of solids and liquids, that no hindrance could be offered to the passage of the motion of the ether known as radiant heat This, however, has been disproved, and Tyndall (to whom we owe nearly the entire treatment of this branch of the subject), has shown that gases and vapours exercise very considerable power upon radiant heat It will be well, before we speak of the results obtained, to indicate the general nature of the apparatus employed, but as it is somewhat complex, those who are specially interested in the subject, may preferably read the detailed description given in the "Philosophical Transactions," or in Professor Tyndall's book on "Heat considered as a Mode of Motion" The main features of the apparatus are, a tube of brass or glass, called the *experimental tube*, capable of being exhausted, and in connection with a barometer tube, so that a gas or vapour of any known pressure may be introduced This tube is closed air-tight with plates of polished rock salt In front of one end of the tube, a cube containing boiling water is placed, and at the other extremity a thermo-electric pile fitted with two cones, one being exactly opposite the rock-salt plate which closes that end of tube, and the other opposite a second cube filled with water kept boiling Thus there are two equal sources of heat which radiate heat upon the opposite faces of the thermopile, the rays from one of which pass through the experimental tube, containing the gas or vapour to be examined, before falling upon the pile These sources of heat are arranged in such a manner that they exactly neutralise each other, and the needle of the galvanometer which indicates the amount of heating, stands at zero If now a gas be admitted into the tube, an inequality will be produced, if it absorbs some of the heat radiated from the cube nearest to it, it is obvious that the other source of heat will predominate, and a deflection of the needle of the galvanometer will result, showing an unequal heating of the opposite faces of the thermopile By experiments on olefiant gas at small pressures, Tyndall found that "when very small quantities of gas are employed the absorption is sensibly proportional to the density" The following table shows the *relative* absorptions of various gases, at the ordinary atmospheric pressure (30 inches of mercury), and at one-thirtieth of that pressure (1 inch of mercury) In the case of gases which readily absorb heat, nearly the whole absorption takes place in the portion of gas which first enters the experimental tube; hence, by diminishing the pressure of gas, the relative absorptions present wide differences, as we see in the second column

ABSORPTION OF HEAT BY GASES (*Tyndall*)

Name of Gas	Relative Absorption		Name of Gas	Relative Absorption	
	At 30 Inches Pressure	At 1 Inch Pressure		At 30 Inches Pressure	At 1 Inch Pressure
Air,	1	1	Carbonic Acid,	90	972
Oxygen,	1	1	Nitrous Oxide,	355	1860
Nitrogen,	1	1	Sulphide of Hydrogen,	390	2100
Hydrogen,	1	1	Sulphurous Acid,	710	6480
Chlorine,	39	60	Olefiant Gas,	970	6030
Hydrochloric Acid,	62	160	Ammonia,	1195	5460
Carbonic Oxide,	90	750			

We thus see that ammonia absorbs no less than 5460 times as much heat as air, at a pressure of one inch of mercury The first four gases absorb scarcely any heat, in fact, as Tyndall expresses it, they act practically as a *vacuum* towards radiant heat, their action is almost a vanishing quantity The comparison of simple with compound bodies presents curious results, the absorption of chlorine is 60 times that of hydrogen at 1 inch pressure, but the absorption of hydrochloric acid (which is composed of equal volumes of hydrogen and chlorine chemically combined), is 160, therefore the compound molecule intercepts more heat, or stops more motion, than either of the single molecules

In the case of vapours the experimental tube was exhausted, and a small flask containing the volatile liquid was then placed in communication with the tube, until the desired pressure was

obtained In the following table the pressures were respectively 0·1, 0·5, and 1 inch of mercury, and the numbers are referred to the absorption of 30 inches (1 atmosphere) of dry air thus $\frac{1}{10}$th of an inch of bisulphide of carbon vapour absorbs fifteen times as much heat as air at the ordinary pressure, while $\frac{1}{2}$ an inch of chloroform absorbs 182 times as much, and 1 inch of acetic ether no less than 1195 times as much.

Absorption of Heat by Vapours, (*Tyndall*)

Names of Vapours	Pressures			Names of Vapours.	Pressures		
	0·1 In	0·5 In	1·0 In		0·1 In.	0·5 In	1·0 In
Bisulphide of Carbon,	15	47	62	Sulphuric Ether,	300	710	870
Iodide of Methyl,	35	147	242	Alcohol,	325	622	
Benzol,	66	182	267	Formic Ether,	480	870	1075
Chloroform,	85	182	236	Acetic Ether,	590	980	1195
Methyllc Alcohol,	109	390	590	Propionate of Ethyl,	596	970	
Amylene,	182	535	823	Boracic Acid,	620		

Tyndall also tried the absorptive power of various perfumes for radiant heat, and found, among other results, that an infinitely small amount of the vapour of otto of roses absorbs 36 times as much heat as air, while spikenard absorbs 355 times as much The action of ozone upon radiant heat is very marked, it absorbs powerfully, and is to be placed beside olefiant gas and the other substances, near the bottom of the tables given above

According to Tyndall aqueous vapour is a powerful absorber of heat The aqueous vapour in the atmosphere was found to absorb 72 times as much heat as dry air itself, and in an atmosphere in which many persons are breathing, it is at least 80 "Looking at the single atoms," writes Tyndall, "for every 200 of oxygen and nitrogen there is about 1 of aqueous vapour This 1 is 80 times more powerful than the 200, and hence, comparing a single atom of oxygen or nitrogen with a single atom of aqueous vapour, we may infer that the action of the latter is 16,000 times that of the former" The effects of this result on certain meteorological phenomena will be noticed elsewhere See also *Diathermancy*, *Dynamic Heating of Gases*

ABSORPTION OF LIGHT All transparent bodies absorb light in a more or less degree It is very seldom that all colours are absorbed uniformly A *selective absorption* usually takes place Thus considerable thicknesses of the purest water show a greenish colour, glass shows a bluish green colour, air, a reddish colour Coloured glasses absorb certain portions of the spectrum and allow others to pass The incandescent atmosphere surrounding the sun and fixed stars absorbs an innumerable number of rays of light, forming what are called the fixed lines of the spectrum The varying absorptive actions which bodies exert upon light cause variations of transparency and opacity See *Atmospheric Lines of the Spectrum*, *Colour, Absorption of*, *Colours of Bodies*, *Blood, Absorption lines in*, *Spectrum*

ABSORPTION OF LIGHT BY DOUBLE REFRACTING CRYSTALS See *Dichroism*

ABSORPTION LINES OF SPECTRA. Certain transparent substances are opaque to certain coloured rays of light, and when they are interposed in the path of a ray of white light which is afterwards submitted to prismatic analysis, this opacity causes gaps to be observed in the spectrum Some minerals, such as the jargon, parisite, some crystallised bodies, such as salts of didymium, erbium, uranium, &c, many metallic solutions, and a few gases and vapours, produce absorption lines of great sharpness, forming systems of more or less complexity Other substances do not produce sharply defined black lines across the spectrum, but carve out bands having an indistinct outline The absorption bands of blood and many organic colouring matters are of this class See *Absorption Lines of Opals*, *Absorption Spectra*, *Blood, Absorption Lines in*, *Spectrum*

ABSORPTION LINES OF OPALS When opals are examined in the spectroscope or spectrum microscope they occasionally show absorption bands crossing the spectrum diagonally or in zigzag paths, Examined in the binocular spectrum microscope the bands sometimes have a spiral structure in relief, moving along the spectrum and rolling over on the axis as the opal is moved across the field of view. The explanation of these phenomena is probably as follows — In the case of the moving line, the light-emitting plane in the opal is somewhat broad and has the property of giving out at one end, along its whole height, and for a width equal to the breadth of the band, say, red light, this merges gradually into a space emitting orange, and so on throughout the entire length of the spectrum, or through that portion of it which is traversed by the moving line in the instrument, the successive pencils (or rather ribbons) of

emitted light passing through all degrees of refrangibility It is evident that if this opal is slowly passed across the slit of the spectrum microscope the slit will be successively illuminated with light of gradually increasing refrangibility, and the appearance of a moving luminous line will be produced, and if transmitted light is used for illumination the reversal of the phenomena will cause the production of a black line moving along a coloured field A diagonal line will be produced if an opal of this character is examined in a sloping position See *Opals, Optical Phenomena of;* also Proceedings of the Royal Society, 1869, p 448

ABSORPTION SPECTRA The system of lines which certain substances produce when the spectrum is viewed through them is called the absorption spectrum In many cases these systems are sufficiently marked to be used as a test for recognising the presence of these substances See *Absorption of Light, Spectrum, Spectrum Analysis*

ACCELERATION (*Acceleratio*, from *ad* and *celero*, to hasten, κέλλειν, to drive, move) The rate of variation of the velocity of a moving point or body It may be uniform or variable When the velocity receives equal increments in equal times the acceleration is said to be uniform, and is then the increase of velocity in a second of time Suppose, for example, that a body is in motion under the action of a force producing a uniform acceleration, and suppose that the velocity at one instant is found to be 30 feet per second, and one second later 45 feet per second, the increase of velocity, or 15 feet per second, is the acceleration

Acceleration is variable when the velocity does not receive equal increments in equal times The acceleration at any instant is then measured by the velocity which would be generated in a second if the acceleration remained constant during the second If, for instance, a body be moving at the rate of 30 feet per second, and its velocity be increasing at that instant so that if the rate of increase be preserved for a second the velocity will be 45 feet per second, then the acceleration is 15 feet per second There may be forces in action which will increase or diminish the rate of variation of the velocity, so that at the end of the second it will not really be 45 feet, nevertheless the acceleration at the particular instant considered is 15 feet per second

It is frequently convenient to consider the whole velocity as made up of two component velocities, and in the same way the whole acceleration may be supposed to result from two component accelerations. When, for instance, a body moves in a curved path, it is frequently convenient to consider the acceleration along the radius vector and perpendicular to it, or along the normal and along the tangent When a point moves in a circle, the normal acceleration is found by dividing the square of the velocity by the radius of the circle From the second and third laws of motion when pressure produces the motion of a body the greater the pressure the greater the acceleration, and the greater the mass moved the less the acceleration The simplest case of a force producing a uniform acceleration is that afforded by the action of the earth on falling bodies (See *Falling Bodies*) The increase of velocity in this case is proportional to the time and nearly equal to 32 2 feet per second

ACCELERATION OF THE FIXED STARS The rate of the stars' apparent diurnal motion is slightly greater than that of the sun's, because the sun's apparent yearly motion takes place (though much more slowly) in a direction contrary to that of his apparent daily motion Compared with the sun the stars thus seem to gain about 3m 56s each day, coming by that interval earlier and earlier each successive day, to the meridian. This apparent gain is called their acceleration

ACCELERATION OF THE MOON, or, *Acceleration of the Moon's mean motion* One of the most interesting peculiarities of the lunar motions It was noticed by Halley, that when ancient eclipses are compared with modern lunar observations, the moon is found to be moving faster now on her course round the earth than in former times The explanation of this peculiarity was for a long time sought for unsuccessfully by the leading professors of the Newtonian system of astronomy, indeed it may be said even now, that the acceleration of the moon is a problem but partially solved We owe to Laplace the first successful attempt to resolve the difficulty He showed that the moon's motion undergoes an acceleration through the slow process of diminution which the eccentricity of the earth's orbit is undergoing Owing to this change, there results (on the whole) a slight diminution of the sun's influence upon the moon's motions The influence of the earth being thus increased, the same effect accrues as would follow from a slight increase in the earth's mass,—in other words, a slight decrease in the moon's period of revolution It has recently been shown by Professor Adams, that Laplace overestimated the effect of this variation in the figure of the earth's orbit, and that, instead of accounting for the acceleration actually observed, as Laplace supposed, it accounts for barely one-half of that acceleration It is the remaining half which remains unexplained Delaunay refers it to a retardation of the earth's motion of rotation, caused by the influence of the tidal wave raised by the moon, but no satisfactory answer has yet been given to the question how

far this cause is capable of accounting for the actual value of the outstanding balance of retardation

. ACCIDENTAL COLOURS When the eye has looked at an intense colour for some time, it appears to become tired and incapable of appreciating that particular colour as readily as it can do other colours Thus, if a red wafer is looked at steadily for a few minutes, and the eye is then suddenly turned to a sheet of white paper, the portion of the retina on which the red image formerly fell being partially tired by the red rays, will not appreciate that component of the white light reflected from the paper so easily as it will the other colours A greenish patch will therefore be observed on the paper This is called an accidental colour, and the image is called an ocular spectrum The accidental colour of the ocular spectrum is always complimentary to the real colour See *Ocular Spectrum*

ACCUMULATED FORCE (*Accumulo*, to heap up, *Cumulus*, a heap) The power of a moving body to overcome resistance When a force acts on a body so as to produce its motion, the force must be in excess of the resistances to the motion, consequently power is imparted to the body at each instant, which is not absorbed by the resistances, this power is called the accumulated force The measure of the power thus developed is the measure of the capacity of the moving mass to overcome any additional resistance which may be opposed to it, thus the accumulated force at any instant is measured by the momentum of the moving body The efficacy of hammers, pile driving machines, fly wheels, and similar contrivances, depends on accumulated force See *Momentum*

ACETAL A colourless liquid, having an agreeable and refreshing odour, prepared by the imperfect oxidation of alcohol by means of platinum black, or by distillation with sulphuric acid and oxide of manganese Its formula is $C_6H_{14}O_2$, its specific gravity is 0 821, it boils at 105° C (221° F), and does not alter by exposure to the air Vapour density = 4 141

ACETATES Combinations of acetic acid with a base are called acetates They are all soluble in water, and for the most part crystallise readily The following are the most important acetates – *Acetate of Aluminium*—This salt only exists in solution, being decomposed by evaporation, it is supposed to have the formula $(C_2H_3O_2)_6 Al_2$ It is largely used in dying and calico printing as a mordant, and is prepared by precipitating alum with acetate of lead, sulphate of lead being thrown down, and a mixture of acetate of aluminium and sulphate of potassium remaining in solution *Acetate of Ammonium*—The neutral acetate is a white crystallin salt of the formula $C_2H_3O_2NH_4$ It is readily soluble in water and alchohol, and evolves ammonia on evaporation, so that it is difficult to obtain pure and crystalline, its solution is known in pharmacy as *Spiritus Mindereri* *Acetate of Copper*—Copper forms several acetates, the normal salt is known as crystallised verdigris It forms dark bluish green prismatic crystals, which are efflorescent and very poisonous, its formula is $C_2H_3O_2Cu$ There are three basic acetates of copper, named respectively the sesquibasic, of the formula $(C_2H_3O_2Cu)_4 Cu_2O$, the dibasic $(C_2H_3O_2Cu)_2 Cu_2O$, the tribasic $C_2H_3O_2Cu\,Cu_2O$ These are all contained in common verdigris, which is largely used both as a pigment and as a mordant in dyeing, it is obtained by submitting metallic copper to the joint action of air and the vapours of acetic acid *Blue verdigris* is almost pure dibasic acetate of copper, and *green verdigris* consists almost entirely of sesquibasic acetate of copper *Aceto arsenite of Copper*—A beautiful, but very poisonous green pigment, known in commerce as *Arsenic green*, *Schweinfurt green*, and *Imperial green*, its formula is $C_2H_3O_2Cu\ 3\,AsO_2Cu$ It is prepared by boiling verdigris and arsenious acid together It is insoluble in water *Acetate of Iron*—Iron forms two acetates, the only one of interest, however, is the ferric acetate, which is generally prepared by mixing per-sulphate of iron with acetate of lead It has not been obtained in the crystalline state, but forms a red-brown solution, which decomposes on ebullition A very crude mixture of the ferrous and the ferric acetate, known as pyrolignite of iron, is largely used as a mordant in dyeing black *Acetate of Lead*—Lead forms a normal, and several basic acetates Normal acetate of lead (known also as sugar of lead) is a white crystalline salt, having a sweet astringent taste, and being very poisonous Its formula is $C_2H_3O_2Pb$ When oxide of lead is digested with a solution of the normal acetate, the tribasic acetate is formed in long silky needles A solution of this salt is frequently used on account of its property of precipitating many vegetable substances, such as gums and colouring matters It is used in medicine under the name of *Goulard Water* *Acetate of Potassium* ($C_2H_3O_2K$), is a very difficultly crystaline salt, deliquescent and melting to a limpid liquid below redness It exists in the juices of many plants, and is prepared artificially by neutralising acetic acid with carbonate of potassium *Acetate of Silver*—This salt is the least soluble of the normal acetates, requiring 100 parts of cold water to dissolve it, it can therefore be prepared by adding nitrate of silver to acetate of potassium, both in strong solution, it then falls down as a white crystalline precipitate Its formula is $C_2H_3O_2Ag$. *Acetate of Sodium* ($C_2H_3O_2Na$), an efflorescent crystalline salt,

prepared by saturating acetic acid with carbonate of sodium. On evaporation it separates in large transparent prisms

ACETIC ACID. (*Acetum*, vinegar) An acid which exists naturally in the juices of several trees. It is, however, almost always prepared artificially either by fermentation of spirit, or by the destructive distillation of wood In the former case the alcohol absorbs atmospheric oxygen under the influence of a ferment, and is converted into acetic acid In this state it is called vinegar, distilled vinegar being the same liquid deprived of its non volatile and colouring matters. Acetic acid is generally prepared from the sour liquid, obtained when wood is submitted to distillation, known as pyroligneous acid The crude liquid is purified by saturation with a base and re distillation with an acid The pure acetic acid when free from water has the composition $C_2H_4O_2$, its specific gravity is 1 0635 At ordinary temperature it is solid and crystalline, and is known as glacial acetic acid It solidifies at about 60° F, and boils at 246° F It has a very pungent sour taste and odour, and blisters the skin Its vapour is inflammable It saturates bases, forming salts which are generally well crystallised. (See *Acetates*)

ACETIC ETHER, or, *Acetate of Ethyl* A colourless liquid having a pleasant ethereal odour strongly resembling that of apples, its specific gravity is 0 932, it boils at 166° F Its composition is $C_2H_3O_2\ C_2H_5$ It is formed by distilling acetate of sodium, alcohol, and sulphuric acid. It is analogous to a metallic acetate, the metal of which is replaced by ethyl.

ACETONE A colourless, very mobile liquid, prepared by the dry distillation of an acetate. Its formula is C_3H_6O It boils at 132° F, and has an agreeable odour and taste resembling that of peppermint, it evaporates quickly producing great reduction of temperature Its specific gravity is 0 792 The term Acetone or Ketone is one applied to a class of bodies composed of an acid-radical united with an alcohol-radical, thus ordinary acetone is methyl acetyl. The following is a list of the Acetones or Ketones at present known —

Methyl-acetyl (Acetone),	$CH_3\ C_2H_3O$
Methyl-butyryl,	$CH_3\ C_4H_7O$
Ethyl-propionyl (propione),	$C_2H_5\ C_3H_5O$
Ethyl butyryl,	$C_2H_5\ C_4H_7O$
Methyl-valyl,	$CH_3\ C_5H_9O$
Trityl butyryl (butyrone),	$C_3H_7\ C_4H_7O$
Methyl cenanthyl,	$CH_3\ C_7H_{13}O$
Tetryl-valyl (valerone),	$C_4H_9\ C_5H\ O$
Amyl-capronyl (capronone),	$C_5H_{11}\ C_6H_{11}O$
Heptyl capryl (caprylone),	$C_7H_{15}\ C_8H_{15}O$
Octyl-pelargonyl (pelargonone),	$C_8H_{17}\ C_9H_{17}O$
Laurone,	$C_{11}H_{23}\ C_{12}H_{23}O$
Myristone,	$C_{13}H_{27}\ C_{14}H_{27}O$
Palmitone or Margarone,	$C_{15}H_{31}\ C_{16}H_{31}O$
Stearone,	$C_{17}H_{35}\ C_{18}H_{35}O$

ACETYLINE A gaseous hydro-carbon of the composition C_2H_2 It is a constituent of coal gas, and may be formed amongst other ways by the direct union of carbon and hydrogen at the high temperature of the electric spark It is a colourless gas, slightly soluble in water, burning with a bright smoky flame Its specific gravity is 0 92 When passed into ammoniacal solutions containing copper or silver, it unites with these metals, forming insoluble acetylides, which when dry explode violently on the application of heat

ACHERNAR (Arabic) A fine star in the southern heavens, the chief brilliant of the constellation Eridanus It does not rise above the horizon of London

ACHROMATIC PRISM Under the head of *achromatism* we have explained how it is possible to obtain refraction without dispersion by placing together two lenses of different kinds of glass By taking prisms of flint and crown glass of such angles that the dispersions are alike, and then placing them together reversed, the pencil of light refracted and dispersed in one direction by the flint glass will be refracted and dispersed in the opposite direction by the crown glass The dispersions being equal in amount will neutralise each other, but the refractions being different there will be a balance of one over the other, and the result will be refraction without any prismatic decomposition of light (See *Achromatism*)

ACHROMATIC TELESCOPE A telescope, the object-glass of which is rendered achromatic (see *Achromatism*) Achromatic telescopes are now universally employed, except when reflecting specula are used One of the best treatises on the general principles of the achromatic telescope is by William Simms, F R S (*The Achromatic Telescope*, London) See also articles on this subject in Nichol's *Physical Sciences*. We have made use of these in the follow-

ing details —In the larger sized telescopes for astronomical purposes the body is usually of one tube In the smaller ones it is formed of several tubes sliding within each other for the sake of portability, this form is applicable only to pocket telescopes used for terrestrial purposes, in which small deviations from straightness will not sensibly impair the performance of the instrument, but such a construction is wholly inapplicable to more powerful telescopes, for which the tubes cannot be too rigid, flexure deranging the concentric positions of the included lenses, and therefore injuring the effect Several rings or *stops* are placed within the body of the telescope, they serve the twofold purpose of strengthening the tube, and of cutting off all extraneous light which, if admitted, would diffuse a foggy or nebulous appearance over the whole field of view, and interfere greatly with distinctness These stops have holes of such diameters, and are arranged at such distances, that the light is limited to the cone of rays converged by the object-glass Care, however, must be taken that the effective aperture of the object glass is not lessened by them, or the advantage of the larger instrument will be lost This may be proved by looking through from the eye end of the telescope without an eye-piece, the eye being in or near the focus of the object glass, under which circumstances the whole of the object glass should be seen, but all parts of the intervening tube should be concealed The stops, and also the inside of the tube, as far as practicable at all events, near the object-end should be covered with a dull black pigment, in order that no light may be reflected in any direction within the tube The performance of a telescope depends, in no small degree, on the accuracy of every part of the work, the tubes should be straight, and the joints and cells very carefully turned and fitted, for if these precautions be not used, the lenses will not have a common axis, a condition indispensable to anything like a satisfactory effect The fitting and fixing of an object-glass within its cell is an operation which requires a great deal of experience The lenses must not be so loosely held as to be at liberty to change their positions, neither must they be so tightly fixed as to incur the smallest risk of being bent or pinched, either by the screwing of the object-cell into the object end of the tube, by contraction of the cell in cold weather, or by any other cause The effect of contraction of the cell in cold weather, for example, is a circumstance which requires a special provision in telescopes of large aperture, for if the cell were made so large, that it could not pinch the glass in extreme cold, it would be improperly loose at the temperature of our warmest seasons It is necessary to warn the inexperienced observer, who may find himself under the necessity of removing his object-glass from the cell for the purpose of cleaning, that care must be taken to replace the lenses in all respects as they were left by the optician The same sides of the lenses must be in contact with each other, and the same face turned towards the object —an error in either of these respects will totally spoil the performance of the object-glass Except in cases of necessity an object-glass should never be removed from its cell The only reasonable excuse for doing so is, the removal of moisture which may have accidentally penetrated between the glasses, and when this has really occurred, inasmuch as its effect will be to produce a permanent stain, and, in some degree, to impair the brilliancy of the instrument, the sooner it is wiped off the better The heavy flint-glass, which has a large quantity of lead in its composition, is peculiarly susceptible in this respect, so much so in some specimens, that exposure for a short time to a moist atmosphere, more especially if it be charged with any appreciable quantity of sulphuretted hydrogen, produces rapid decomposition of the polished surface A soft silk handkerchief, or a carefully chosen piece of chamois leather, may, perhaps, be most safely used for wiping the surfaces of an object-glass, and the application of a few drops of alcohol will assist in removing any impurities that adhere to the surfaces of the lenses When nothing but loose particles of dust require to be removed, a soft camel's hair brush is by far the best instrument for the purpose Necessary, however, as an observer may find it, in the event of an accident, to meddle with his object-glass, it is much better, if possible, to avoid doing so altogether, and to this end the utmost care should be taken to keep it out of the reach of dust or moisture A telescope used at night in the open air should be furnished with a dew-cap, which is a cylinder of metal, black within and bright without, and made to fit upon the object-end of the telescope, its length varying from 8 to 18 inches, according to the aperture of the glass This, under ordinary circumstances, will prove a sufficient defence In testing the quality of an object-glass the considerations especially to be attended to are the purity of the material and the correction of the two kinds of aberration, the spherical and the chromatic' It will, of course, be obvious that in addition to these matters, good workmanship in the formation of the curves, and judicious mounting and adjustment within the cell, are conditions indispensable to fine performance, for even with good materials, and due attention to theory, it is impossible to produce a good object glass without a competent degree of practical skill in working and mounting the lenses of which it is composed Some judgment as to the purity of the glass may be formed in the following manner —Direct the telescope to the moon's limb, or to the planet Jupiter. Take out the eye-piece, and place the eye in or near the

focus of the object-glass Then if the eye be moved about so that the patch of light, with which the object-glass appears partly filled, be made to pass and repass slowly across its surface, any irregular refractions, and especially the presence of veins, will be immediately detected With regard to the spherical and chromatic aberrations, the extent to which the first has been eliminated, will be shown by the permanence of the focus, whether the image be formed by the centre or by the circumference of the object-glass, and the last by the absence of the more brilliant colours of the spectrum, for a perfect reunion of all the colours is in general unattainable For the adjustment of an object glass, an artificial star, formed by the sun's image reflected from a polished hemisphere of dark coloured glass, or the ball of a broken thermometer tube placed at any convenient distance, say from thirty to sixty yards, is an excellent object, so likewise is a small circular white disc upon a black ground The image should appear sharp and well defined, and if, on being put a little out of focus, the enlarged disc does not expand equally all round, but presents an elongated figure in one direction, the defect is generally attributable to the mounting—not to the glass—and arises from the object end being tilted upon the tube The performance of a telescope depends more upon the eye piece than is ordinarily imagined A bad eye piece will undo the work of a good object glass, and consequently too much care cannot be used in making a selection The loss of light by reflection and absorption in an eye-piece consisting of two or more lenses has induced some observers to give the preference to a single lens, either convex or concave, and if such a lens be made achromatic one very serious objection to its use is to a great extent removed There will remain, however, the inconvenience of having so small a field of view that the working of a telescope with such an eye-glass, especially if it have any high degree of magnifying power, is troublesome and embarrassing in the extreme The eye piece most in use, and altogether best adapted for astronomical purposes, is the *Huygenian* or *Negative* eye piece, (which see) *Ramsden's* or the *Positive* eye piece is sometimes used for micrometric work, and the *Erecting* eye-piece is used for terrestrial telescopes The way in which a telescope is mounted is by no means a matter of indifference Many first rate instruments are little used or used to no good purpose for want of being firmly supported and fitted with such mechanical means as would enable the observer to find an object and examine it at his leisure The different forms of stand are —The pillar and claw stand, for telescopes of from 30 to 45 inches focal length This stand is sometimes furnished with vertical and horizontal rack movements giving slow motions, by means of which the observer may follow a star much more perfectly and with greater facility than he would by merely pressing the telescope forward by hand Larger telescopes are generally mounted equatorially, or as meridian instruments See *Achromatism*, *Eye piece*, *Negative Eye-piece*, *Positive Eye piece*, *Object glass*, *Telescope*, *Telescope, Magnifying power of*

ACHROMATISM (α, without, χρῶμα, colour) It has been found that prisms of different kinds of glass cut to produce spectra of the same length refract them differently, and *vice versa*, when cut at such an angle that they have the same mean refraction, the length of the spectrum or dispersion will be different Now, if a prism of flint glass be taken it will produce a certain amount of refraction and of dispersion, and if a similar shaped prism of the same glass be placed behind it, in the reverse position, the refraction and dispersion in one direction by the first prism will be exactly neutralised by the refraction and dispersion in the opposite direction by the second prism, and as a result there will be no refraction and no colour But suppose a prism of *crown glass*, having the same dispersion as the one of flint glass, be placed behind the latter in the reverse position, the two dispersions being opposite and equal will neutralise each other, and the result will be white light, but the mean refractions being different these will not neutralise each other, and the beam of light will pass through free from colour, or achromatic, but refracted more or less As a lens may be looked upon as a combination of prisms with curved surfaces, achromatic lenses may be produced in the same way as achromatic prisms Absolute achromatism is impossible, owing to the spectra from different dispersive media not having an exact proportionality to one another This is called irrationality of dispersion It may be cured in some degree by introducing a third lens of plate glass in addition to the flint and crown glass lenses An under corrected lens is one in which the correcting lens of flint glass does not quite accomplish the purpose, and in this case the violet ray will come to a focus a little within the red In an over corrected lens the error is of the opposite kind, and the order of colours will be inverted

ACID (*Acidus*, sour) A class of chemical compounds which have certain properties in common They may be considered as salts of the metal hydrogenium, or hydrogen The general properties of the most important acids are, solubility in water, sour taste, power of reddening litmus, the power of decomposing carbonates with effervescence; the power of neutralising alkalies and bases, forming salts. The progress of modern chemistry is gradually

rendering the term acids less definite, and it is not improbable that it will be dropped altogether in strictly scientific writing, although in ordinary chemical language it will be retained as a convenient term for expressing a very wide class of substances All the above characteristics are seldom possessed together, many acids having only one or two of these properties, and some substances which are not acids possessing all of them Thus silicic acid is not soluble in water, has no sour taste, and does not redden litmus Perhaps the most correct definition of an acid is that of a salt of hydrogen, capable of forming salts with other bases, this, however, only removes the difficulty of defining what an acid is to the equally great one of defining what is a *salt* and what is a *base*

ACIDIMETRY (*Acidus*, *μετρέω*, to measure) The determination, either by volumetric analysis, or by direct weighing, of the amount of real acid contained in acid solutions Suppose, for example, we require dilute sulphuric acid, before the solution can be used with any certainty in many processes, it is necessary to know the actual amount of SO_3 in 100 parts of the hydrated acid

ACLINIC LINE (*α*, without, *κλίνω*, to incline) Referring to Terrestrial Magnetism, the aclinic line is the line passing through all the points on the earth's surface which have zero magnetic *inclination* or dip That is to say, the points at which a dipping needle assumes a horizontal position (See *Dip*, *Magnetic*) This line is also called the Magnetic Equator It is a somewhat sinuous line, differing not much from a great circle of the earth, and cutting the geographical equator in two parts, one of which is in the Atlantic Ocean near the west coast of Africa, and the other nearly 180° distant from the first At these points the aclinic line is inclined to the geographical equator at an angle of about 12°, lying in the Eastern hemisphere to the north, and in the Western to the south of it (See *Magnetism*, *Terrestrial*)

ACONITINE The active principle of the monkshood (*Aconitum Napellus*) It is difficult to obtain crystalline, but generally forms a white pulverulent or compact vitreous mass, possessing no odour, but a strong bitter taste, it is very soluble in alcohol, less so in water, it melts at 176° F The solution has an alkaline reaction, and neutralises acids, forming salts, which are not easy to crystallise Aconitine and its salts are intensely poisonous

ACOUSTICS (*ἀκούω*, to hear) Properly the science of hearing, but at present no distinction is made between the science of sound and acoustics See *Sound*

ACROLEIN A colourless mobile liquid lighter than water, and boiling at 52° C (126° F), It possesses a highly irritating action upon the eyes, which renders working with this substance almost insupportable Formula, C_3H_4O It is readily inflammable, dissolves slightly in water, and is a product of the destructive distillation of fatty substances, being produced from the glycerine which they contain Oxidation converts it into *acrylic acid*, $C_3H_4O_2$

ACRONYCAL (*ἄκρος*, at the summit, and *νύξ*, night) Sometimes, but incorrectly, written *achronical* A celestial object is said to be *acronycal* when it is opposite the sun, and so culminates at midnight When a star rises as the sun sets, it is said to rise acronycally, and conversely, to set acronycally, when it sets as the sun sets In ancient astronomy three different modes in which a star's rising or setting might be related to the sun's, were recognised, viz , the acronycal, the *cosmical*, and the *heliacal*

ACRYLIC ACID See *Acrolein*

ACTINIC INTENSITY OF DAYLIGHT See *Daylight, Actinic intensity of*

ACTINISM (*ἀκτίν*, a ray) A term first employed by Robert Hunt, to express the chemically active or photographic rays of light When a solar spectrum is examined by appropriate means it is found that the visible portion by no means constitutes the whole of it Beyond the red end the heat rays extend, whilst beyond the violet the spectrum is extended for a considerable distance, consisting of what is termed the actinic, ultra violet, fluorescent, photographic, or chemical rays of light When a solar spectrum of considerable purity is allowed to fall on a sensitive photographic plate containing iodide of silver, no effect is produced by the ultra red, the red, orange, yellow, green, or blue rays, the action commences at about the fixed line G, and continues under favourable circumstances of atmospheric transparency to a distance exceeding by about seven times the visible limits of the solar spectrum This photographic impression is seen to be furrowed across with a great number of lines of all degrees of width, sharpness, and intensity, showing that the fixed lines of the spectrum are not confined to the visible portion These lines can also be rendered visible by receiving the spectrum on a screen of some fluorescent substance (see *Fluorescence*), such as uranium glass, or a card washed over with sulphate of quinine solution There is no sharp distinction between these actinic rays and the visible rays, in fact, the violet and indigo may be considered both light and actinism, in the same way as the extreme red rays may be considered as light and heat Although, therefore, the term actinism is not accurate, as applied to a *portion* of the spectrum, it is a very convenient expression for a property of that portion (See *Spectrum*, *Fluorescence*)

ACTINOMETER (ἀκτίν, a ray, and μετρέω, to measure) An instrument for measuring the amount or intensity of the actinic or chemical rays of light Several contrivances have been proposed to effect this object, thus a sensitive surface of chloride of silver is found to darken, when exposed to light, in proportion to the intensity of the light and the duration of exposure, and since this darkening is produced entirely by the actinic rays, the depth of tint produced by (say) five minutes' exposure will give an approximate idea of the intensity of the actinism present The difficulty in this case is to prepare chloride of silver paper which shall always have the same amount of sensitiveness. The chemical photometer of Professors Bunsen and Roscoe (Phil Trans, 1863, p 139), is based upon this principle Dr Draper employed for this purpose the reaction originally observed by Gay-Lussac and Thénard, that chlorine and hydrogen when mixed in equal volumes do not combine in the dark, whilst they unite to form hydrochloric acid when exposed to the actinic rays of light Draper discovered the important law that this action varies in direct proportion to the actinic intensity of the light, and to the time of the exposure Professors Bunsen and Roscoe have devised an instrument, which they call the "Chlorine and Hydrogen Chemical Photometer," based upon this principle, and by ascertaining the conditions necessary for giving accuracy, they have placed the subject of the measurement of the chemical action of light upon an exact scientific basis For further particulars see the original memoirs of these chemists (Phil Trans, 1857, pp 355, 381, 601, 1859, p 879; 1862, p 139) Other actinometers have also been proposed, based upon other chemical reactions, thus a solution of chloride of gold and oxalic acid will remain clear in the dark, but precipitates metallic gold when exposed to the actinic rays. Several other reactions of this kind are known in chemistry, and might possibly be utilised (See *Actinism*, *Photometer*)

The term actinometer has also been applied to a thermometer for measuring the heating effect of direct solar rays One of these consists of an ordinary mercurial thermometer, with a large bulb and an open scale, observations are made by placing it alternately in shade and in sunshine for equal intervals, and noticing the difference between the readings The Rev G C Hodgkinson has described (Pro R S, Jan 1867) an instrument of this kind. It cannot be too much regretted that a name which, by universal consent, has hitherto been used in reference to the chemical rays of light should be applied to an ordinary thermometer

An instrument invented in 1825 by Sir John Herschel for measuring the intensity of the sun's heat was the first to receive the name of actinometer It differs from the pyrheliometer of Pouillet, in the mode of indicating the absorbed heat, the amount of which is shown by the expansion of a solution of ammonio-sulphate of copper, produced by the action of the sun's rays on a known area of the vessel containing the expanding liquids The results obtained by Herschell and Pouillet, with their different instruments, agree very closely (See also *Heat, Sources of*, *Pyrheliometer*)

ACTION AND REACTION In mechanics, the effort exerted by a power on the body on which it acts Action may be exerted for an appreciable time, as in the case of pressure, or for an indefinitely short instant of time, as in the case of percussion Action is always met by a resistance termed a *reaction*, and it is an axiom of mechanics that *action and reaction are equal and opposite.* This is Newton's third law, and was proved by him by many experiments The following are illustrations of the axiom —When a weight rests on a table, the table presses against the weight with a force equal to the pressure exerted by the weight on the table When one ball strikes another, the force with which the second tends to stop the first is equal to that with which the first tends to move the second.

ADARA (Arabic) The star ε of the constellation Canis Major.

ADHESION. (*Adhæreo*, from *ad*, to, and *hæreo*, to stick) The force which keeps the particles of unlike bodies in the same relative positions with regard to each other It is applied to the union of dissimilar bodies only, and is therefore opposed to *cohesion*, which is the force existing between particles of like nature Thus it is the force of cohesion which keeps together the particles of a piece of lead, but the force of adhesion which causes two plates of lead and tin to remain together after being subjected to pressure When solids immersed in liquids are wetted by them, it is because the force of adhesion between the solid and liquid is greater than the force of cohesion between the particles of the liquid themselves Glass plunged into mercury is not wetted, there being no force of adhesion between the two substances When the adhering liquid solidifies the adhesion is greatly strengthened This is the case with cements, which frequently adhere to a body with greater force than the force of cohesion with which the particles keep together The substances used as cements present various gradations of adhesive power, and are usually so chosen that the forces of adhesion and cohesion are nearly equal,—thus, glue is used for wood, resinous materials for glass or china, calcareous matter for stone or brick Adhesion between solids is one of the causes of the passive resistance known as friction. (See *Friction*)

Adhesion is promoted by liquidity, so that very many liquids freely mix with or dissolve one another In the case of the more viscous liquids, which are but sparingly dissolved by water, the struggle between their adhesion to water and the cohesion of their particles gives rise to the phenomena known as Cohesion Figures (See *Cohesion Figures*) Various manifestations of adhesion appear in capillary attraction, diffusion of liquids, osmosis, diffusion of gases, &c (See articles on those subjects—also *Cohesion*, *Aggregation*)

ADHESION BETWEEN LIQUIDS AND SOLIDS It is observed that, when certain solids, such as clean glass, are plunged into water, the horizontal surface of the water is raised in the neighbourhood of the glass, and reaches some distance up its sides, forming a concave curved surface If the glass be coated with grease before being plunged in the water, the water is no longer level in the neighbourhood of the solid, it curves downwards as it approaches the grease, forming a convex surface Again, if a piece of clean platinum be plunged into mercury, the mercury rises up the side of the platinum as water rises up the side of the glass And if glass be plunged into mercury, the mercury is depressed in its neighbourhood, as was the water in that of the grease Accordingly, whether the surface of the liquid in the neighbourhood of the solid be convex or concave, depends upon the nature of the liquid and of the solid which are in contact Whenever the concave surface is produced, the solid, when withdrawn, is found to be wetted with the liquid Whenever the convex surface is observed, the solid, when withdrawn, is found to be free from the liquid This already points in the latter case of the superiority of the cohesion of the liquid over the adhesion between the liquid and solid, and, in the former case, of the superiority of the mutual adhesion over the liquid's cohesion This is clear if we consider the forces at work Imagine the liquid to be horizontal The cohesion of the liquid will tend to urge it to assume a spherical form, that is, to acquire a rounded edge, to assume which shape it must leave the solid This force may be represented by a single force, C, bisecting the angle contained between the surface of liquid and the immersed wall of solid There will be adhesion in the region of contact which will be exercised with equal force, A, in two directions, the one bisecting the angle between the projecting surface of the solid and the continuation of the liquid surface (into the solid), the other, at right angles to this, bisecting the continuation of the liquid surface and the submerged wall of solid The vertically upward and downward tendencies of the two forces, A, will be equal and opposite, and they therefore may be neglected The resultant will be $2 A \cos 45°$ The horizontal tendency of the force C is $C \cos 45$ Therefore, the proportion between the tendency towards the wall (due to adhesion), and the tendency away from the wall (due to cohesion), is that of $2 A$ to C If, therefore, the cohesion is more than twice as great as the adhesion, the former will prevail, and the liquid will rise up the side of the containing vessel If the cohesion is less than twice as great as the adhesion, the latter will prevail, and the liquid in the neighbourhood of contact will be rounded If the two are equal ($2 A = C$), a perfectly flat liquid surface will be preserved up to the solid (See *Capillarity*)

ADIPOCERE (*Adeps*, fat, and *cera*, wax) A peculiar fatty substance, resulting from the slow decomposition of animal matter in a moist locality It consists chiefly of solid fatty acids Fourcroy gave an account in 1789 before the Académie des Sciences of the opening of a grave in one of the Paris cemeteries, in which he found a shrunk body, in various parts of which were lumps of adipocere

ADJUSTING SCREW (*Adjustare*, from *ad*, and *justus*, just, right) See *Clamp*

ADJUTAGE A tube through which the water of a fountain is discharged

ÆLOPILE (*Æolus*, god of the winds, and *pila* a ball) A hollow sphere of metal, furnished with a tube terminating in a small orifice When water is introduced into the sphere, and it is placed over a fire, steam is formed, and rushes from the mouth of the tube, producing a more or less violent blast The ancients, to whom the ælopile was well known, considered that the water was converted into air, and were wont to illustrate the production of winds by the above means The ælopile was much used during the early period of scientific research, and is not unfrequently mentioned by Robert Boyle (17th century) Perhaps the earliest mention of it is in the πνευματικα of Hero of Alexandria

ÆOLIAN HARP A musical instrument, named from Æolus, the heathen god of winds, in consequence of its music being produced by the action of the wind It consists of a box of thin deal, of a length equal to the width of the window in which it is to be placed, its depth five or six inches, and width seven or eight inches Along the top of the box a variable number of catgut strings are fixed, passing over two bridges placed transversely, and attached to pegs at each end of the box Thus the strings can be tuned to any required note, and generally all are tuned to the same note. When the instrument is placed with the strings outward in the window to which it is fitted, and the wind blows on the window, sounds resembling the singing of a distant choir are produced, varying in intensity with the strength of the wind. The num-

ber of strings is usually seven, ten, or fifteen, and occasionally the two extreme strings are tuned to two octaves below the others

ÆPINUS CONDENSER (constructed by Æpinus about 1753), is an instrument for collecting electricity. Its principle depends upon induction, and the apparatus is much used to illustrate the phenomena of induction, and to explain the principle of the Leyden jar (See *Condenser*)

ÆPINUS' THEORY explains the phenomena of magnetism by supposing a fluid which pervades magnetic bodies, such as iron, cobalt, and nickel The particles of this fluid are assumed to repel each other, but to attract the particles of the iron, nickel, &c He, moreover, supposes the particles of the iron or nickel to repel each other, and explained on this assumption the well-known laws of magnetic attraction and repulsion

AERO DYNAMICS (ἀήρ, the air, and δυναμις, power) The science which treats of the motion of the air, or of the mechanical effects of air put in motion

AEROLITE (ἀήρ, air, and λιθος, a stone) The name given to those stony and metallic masses which reach the earth's surface from the interplanetary spaces, after passing, with or without explosion, through the atmosphere The interpretation of the phenomena presented in common by aerolites, bolides, and shooting stars, is dealt with under the head, *Meteors, Luminous*. Here, therefore, we shall consider only the peculiarities distinguishing this particular class of bodies from their fellow travellers amid the interplanetary spaces

From the earliest ages we find records of the fall of aerolites "It is a fact," says Sir John Herschel, "established by the most indisputable evidence, that stony masses and lumps of iron do occasionally, and, indeed, by no means unfrequently, fall upon the earth from the higher regions of our atmosphere (where it is obviously impossible that they can have been generated), and that they have done so from the earliest times of history Four instances are recorded of persons being killed by their fall" In the year B C 465, a stone fell at Ægos Potamos, which is described as being equal to two mill stones in volume Four centuries after its fall this stone continued to be an object of interest, but afterwards it appears to have been lost sight of Humboldt recommends that travellers in Thrace should search for it On November 7, 1492, an aerolite fell at Ensisheim in Alsace It was preserved as a relic in the cathedral of Ensisheim until the French revolution At present it is preserved in the public library of Colmar The Emperor Jehangire had a sword forged for him from a mass of meteoric iron which fell at Jahlinder in 1620 Amongst many other modern instances may be mentioned the fall of aerolites at L'Aigle in Normandy in April 1803 In this instance it would seem that a mass of vast size had exploded in the upper regions of air, for the fall was preceded by the appearance of a small black cloud, which suddenly broke up with a violent explosion Upwards of 2000 fragments were collected from different parts of a region measuring seven miles in length and three in breadth Some of these weighed only a few drachms, the heaviest about 17½ lbs There are sixteen well-authenticated instances of the fall of aerolites in England and Scotland, while four have been recorded as having fallen in Ireland, and two meteoric stones have been found in Scotland

Professor Shepherd (of America) asserts that the fall of aerolites "is confined principally to two zones, one belonging to America, bounded by 33° and 44° north latitude, and about 25° in length Its direction," he adds, "is more or less from north-east to south-west, following the general line of the Atlantic coast Of all known occurrences of this phenomenon, during the last fifty years, 92 8 per cent have taken place within these limits, and mostly in the neighbourhood of the sea The zone of the eastern continent—with the exception that it extends ten degrees more to the north—lies between the same degrees of latitude, and follows a similar north-east direction, but is more than twice the length of the American zone Of all the observed falls of aerolites 90 9 per cent have taken place within this area, and were also concentrated in that half of the zone which extends along the Atlantic" The results here mentioned are interesting, but not for the reasons stated It has been well remarked by Mr Townshend Hall that the zones referred to by Professor Shepherd are simply those zones which are most thickly peopled But it is worthy of notice, as a legitimate conclusion from these figures, that we must largely add to the number of recorded falls, if we wish to estimate justly the total number of aerolites which fall in a given time upon the earth.

The mass of many aerolites affords striking evidence that within the interplanetary spaces there must exist a large amount of material traveling as yet freely around the sun In the Imperial Museum at St Petersburg there is a mass of meteoric iron weighing no less than 1680 lbs, while it has been estimated that an unweighed aerolite which lies on the plain of Tucuman, near Otumpa, in South America, cannot fall short of 15 tons in weight In the British Museum there is an aerolite which weighs more than 5 tons

The composition of aerolites is exceedingly diverse. Iron is almost always present, as also a

percentage of nickel and cobalt Copper, chromium, manganese, tin, and molybdenum have also been found in aerolites Carbon is sometimes, though but rarely, found Such minerals as hornblende, augite, and olivine are commonly met with Twenty two elements, not one of which is new, have been recognised in aerolites But though we find no new elements in these bodies, we see, not only in the way in which they are compounded, but also in their structure, the clearest signs of a non terrestrial origin The proportion of iron commonly found in aerolites is, for example, wholly in excess of that recognised in terrestrial substances, while we learn from the researches of Sorby, D'Aubrée, and others, that aerolites have been subject to the action of a heat so intense, and to processes of crystallisation so energetic, that no appliances known to our chemists could produce corresponding effects

Reasoning from probability, it is difficult not to conclude, that for every aerolite, which has fallen upon the earth within historic times, there must be millions which have reached the earth during the eras recognised by geologists, and that the total mass thus added to the earth from without must amount, at least, to many millions of tons Again it is clear that not our earth alone, but all the planets of the solar system, our moon and the other satellites, every orb, in fact, which obeys the attraction of the sun, must be liable to encounter, at longer or shorter intervals these wandering masses, to which Humboldt has given the expressive name of 'pocket planets" Nor can we recognise as just, in the face of all this evidence to the contrary, the view expressed by one of our leading astronomers that the united weight of all the bodies of the solar system, other than the sun, planets, asteroids, satellites, and Saturn's ring, must be weighed rather by grains than by tons

Much useful information on the subject of aerolites will be found in Dr Phipson's treatise on meteors, aerolites, and falling stars

AERONAUTICS (ἀήρ, air, and ναυτικός, pertaining to ships) The art of navigating the air The term is commonly applied to balloon-voyaging (see *Balloon*), but should properly be limited to the as yet, unlearnt art of guiding aerial vessels

It seems to have been abundantly demonstrated that balloons cannot be guided through the air their very buoyancy placing them beyond the control of those whom they support above the level of the earth Many have, indeed, been led to regard this circumstance as opposing an insurmountable obstacle to aerial voyaging, since it appears as though the very means by which alone men can be supported above the ground must prevent them from urging their way at will through the air But recent inquiries have tended to show that the art of aerial voyaging is not so hopelessly unattainable as had been supposed In fact the true principles on which aerial flight may be said to depend have only of late years been fairly recognised The formation of a society, called the Aeronautical Society of Great Britain, presided over by the Duke of Argyll, and including in its ranks several of our ablest men of science, has attracted a large share of attention to a subject hitherto commonly regarded as little worthy of consideration, and it seems far from improbable that results of considerable importance will follow from the inquiries which have recently been made into the principles of flight

It has been shown, in the first place, that the extent of supporting surface need not be proportioned to the weight to be carried M de Lucy has made a careful study of numerous birds and insects, with the object of determining the relation between weight and supporting surface We quote some of his results from a valuable paper on flying machines, by Mr Brearey, honorary secretary to the above named society —' M de Lucy asserts that there is an unchangeable law to which he has never found any exception amongst the considerable number of birds and insects, whose weight and measurement he has taken, viz, that the smaller and lighter the winged animal is, the greater is the comparative surface Thus in comparing insects with one another, the gnat, which weighs 460 times more than the stag-beetle, has 14 times greater relative surface The lady-bird, which weighs 150 times less than the stag-beetle, possesses 5 times more relative surface, &c It is the same with birds The sparrow, which weighs about 10 times less than the pigeon, has twice as much relative surface The pigeon, which weighs about 8 times less than the stork, has twice as much relative surface The sparrow, which weighs 339 times less than the Australian crane, possesses 7 times more relative surface, &c If we now compare the insects and the birds, the gradation will become even more striking The gnat, for instance, which weighs 97,000 times less than the pigeon, has 40 times more relative surface, it weighs 3,000,000 times less than the crane of Australia, and possesses, relatively, 140 times more surface than the latter, which is the heaviest bird this author had weighed, and it was that which had the smallest amount of surface, the weight being 20 lbs 15 oz $2\frac{1}{4}$ dr avoirdupois, and the surface 139 square inches per kilogramme (somewhat more than 63 square inches per lb), yet, of all travelling birds, they undertake the longest and most remote journeys, and, with the exception of the eagle, elevate themselves highest, and maintain flight the longest "

M de Lucy does not notice the tendency in these numbers towards a somewhat remarkable relation It would appear almost as though the supporting surface increased as the cube root of the weight, for though this relation is not exactly presented in all the above instances, it is approximated to in most of them Taking also the widest range, and comparing the numbers 3,000,000 and 140, we see that the relation is approximated to in a very significant manner, considering the wide diversity between the characteristics of the gnat and the Australian crane.

It would appear, then, that the supporting surface necessary to sustain a man would be very much less than has been hitherto supposed And what is more to the purpose, a properly devised aerial machine, intended to convey many persons at once, need by no means have that enormous extent of supporting surface which has been hitherto proposed for such machines

But another circumstance of considerable importance has been noticed during recent inquiries. It has been shown that propulsive velocity is a very important element in the question When a bird beats his wings up and down, for example, it might be thought that the movement was intended to raise the body of the bird, in reality, however, the object of the movement is commonly to secure a motion directly, or almost directly, *forwards* Support is secured, not by the greater effectiveness of the downward beat, as compared with the upward motion of the wing, but by the rapid transference of the bird's body over continually new regions of air It has been shown, indeed, by Dr Pettigrew, that the action of a bird's wing in moving both upwards and downwards, resembles that of a screw propeller The present writer has been much struck by the singular horizontality of a pigeon's motion on first leaving level ground, the wings beating sharply upwards and downwards, but the bird's body advancing in a straight line

It is probable that we may find, in the circumstance just considered, the explanation of the relation before dealt with which subsists between weight and supporting surface, for the larger birds and insects can propel themselves more rapidly than the smaller, and so gain support from a greater range of air

It would seem only possible, therefore, to master the difficulties of aerial voyaging, by securing powerful propulsive appliances, and it may not unsafely be predicted that if ever the problem is mastered, the means will at the same time be discovered of voyaging most rapidly from place to place

For an interesting account of various attempts which have been made to voyage through the air, the reader should consult Hatton Turnor's *Astra Castra*

AEROSTATION A term commonly used to signify the art of guiding aerial vessels (See *Aeronautics*)

ÆSCULIN A crystallised substance extracted from the bark of the horse-chestnut (*æsculus hippocastanum*) It forms colourless needle shaped crystals, which have a bitter taste, formula, $C_{21}H_{24}O_{13}$ It is interesting, because its aqueous solution is highly fluorescent, with a beautiful sky blue colour (See *Fluorescence*)

ÆTHRIOSCOPE (*αἴθρος*, clear, and *σκοπέω*, to view) An instrument for measuring the radiation towards the sky It was invented by Sir John Leslie, who, however, was not able satisfactorily to interpret its indications It consists of a differential thermometer, one bulb of which is placed in the focus of a metallic cup, which protects it from terrestrial radiation, but, when uncovered, permits it to radiate its heat freely towards the sky The other bulb is protected in such a way that its temperature is the same as the air throughout the experimental use of the instrument If now the metallic cup is uncovered, the exposed bulb will lose heat by radiation towards the sky, and as the other will keep its temperature unchanged, the motion of the column of liquid in the tube of the differential thermometer will indicate how much heat is lost by radiation from the exposed bulb Leslie was perplexed by finding that the loss of heat was not proportional to the apparent clearness of the sky He found indeed that even a passing cloud seemed to check the loss of heat, but "sometimes," he says, "under a fine blue sky the æthrioscope will indicate a cold of 50 millesimal degrees, while, on other days, when the air seems equally bright, the effect is hardly 30°" The difference is due to the presence, on the last-named days, of invisible aqueous vapour in the air, and to the fact that such vapour checks the radiation of heat from the æthrioscope

AFFINITY, in chemistry, means the tendency of *different* kinds of matter to unite; although it is customary in modern chemistry to object to the term on the ground that, in ordinary non-technical language, it means "resemblance," whereas bodies that *least* resemble each other—such as copper and sulphur, iodine and phosphorus—unite with the greatest energy, while bodies that *most* resemble each other, such as chlorine, bromine, and iodine, have but little chemical affinity for each other But the word affinity also means "relationship" and "ties of family," and it is in this sense that the metaphor is properly used in chemistry, indicating not a "resemblance," but "a disposition to unite." In this sense the term was first brought into use by

Boerhaave as early as 1732. Others give the credit to Geoffroy, who published his Tables of Affinity in 1718 The influence of Newton in this country, and the jealous feeling entertained towards France, led our philosophers to prefer the term "chemical attraction," which introduced a mechanical idea into chemical work, and thus produced confusion of thought, which, as stated above, still prevails

Affinity is exerted within incommensurable limits, amounting to what is popularly called "contact." Tartaric acid and sodic carbonate, for example, exert no action if mingled together in the form of dry powders, but, by the addition of water, they enter into solution and thus exercise that close adhesion which insures energetic chemical action

Geoffroy's Tables, already referred to, indicate the order in which bodies displace each other, and thus mark to some extent the force of affinity For example, in the following table certain bases are arranged in the order in which they displace each other from the salts which they form respectively with sulphuric acid —

SULPHURIC ACID.

Baryta.	Soda	Ammonia
Potash	Lime	Zincic Oxide.

Affinity produces an entire change in the properties of the bodies brought together, thereby distinguishing affinity from mechanical action Thus, magnesia, mixed with water, produces scarcely any chemical change, for, by passing the mixture through a filter, nearly the whole of the magnesia can be separated, but if to the mixture a little sulphuric acid be added, a true chemical combination takes place by virtue of the affinity existing between magnesia and dilute sulphuric acid We get a new compound, with properties different from those of the components. The acid is sour and caustic, the earth is insipid and alkaline, the compound is bitter, forming the well known *Epsom salts*.

Hence there is a specific difference between a mechanical or physical phenomenon and a chemical In one we get the *mean* of the properties of the component parts, in the other we get *different* properties—a new body in fact

In the exercise of affinity there is no destruction of matter There may be, and often is, change of state, as from the solid to the liquid or gaseous, and the gases may escape unnoticed by the unskilled eye, but the chemist knows how to collect and account for all the results of chemical change

Under the influence of affinity bodies sometimes unite *directly*, as when hydrogen, burning in air, unites with oxygen and forms water, or by *substitution* or *displacement*, as when, in the table just given, baryta displaces any one of the earths below it from union with sulphuric acid

In many cases affinity requires to be promoted by the action of a high temperature, as in the case of charcoal, which must be ignited before oxygen will unite with it Affinity also produces a change in temperature, in some cases greatly above, in others below, that of the atmosphere

When bodies unite by virtue of affinity they do so in definite proportions, and this naturally leads us to refer to *Atomic Theory*

For the electrical theory of affinity we must refer to *Electro-negative* and *Electro-positive* Those who would account for affinity entirely on electrical grounds, have failed to point out by what force the components of the compound are held together

AGATE (*ἀχάτης*) A mineral consisting of quartz, coloured by various substances, and sometimes blended with jaspar and carnelian There are several different kinds known as *Moss agate*, *Fortification agate*, *Ribbon agate*, &c, from the appearance of the interspersed substances

AGGREGATION (*Aggrego*, from *ad*, and *grego*, to collect into a flock or herd—from *grex*, a flock or herd)

Material particles naturally exist in three different conditions or states of aggregation—namely, solid, liquid, and gaseous In the solid state, cohesion binds the particles so closely together that they are not capable of freely gliding over one another, and the body maintains the same shape until some external force acts upon it with sufficient intensity to separate the particles violently from one another, and to break, crush, stretch, or otherwise alter it Metals and rocks are examples of solids

In liquids, the forces of cohesion and repulsion almost equally balance each other, the particles not cohering so strongly as to be incapable of easily gliding over one another, and not tending to fly off from each other by the influence of repulsion. Thus, liquids readily accommodate their figures to the shapes of the vessels in which they are placed, and when a liquid is placed on a plane, it spreads out evenly over the surface of the plane

In gases there is not only an absence of cohesion, but a force of repulsion amongst the par-

ticles, so that the natural tendency of gaseous particles is to separate one from another Thus gases are capable of indefinite expansion

All bodies are supposed to be capable of existing at various times in all these states Thus water may be changed by cold into ice, and by heat into steam All known liquids can be converted into vapours, and very many gases can be liquified and solidified by cold and pressure Wherever liquids or gases have not yet been solidified, it is assumed by analogy that such a condition would be possible if we could apply a sufficient degree of cold (See *Attraction, Repulsion, Adhesion*)

AGONIC LINE (*a*, without, *γωνια*, an angle) The name applied in terrestrial magnetism to the line which joins all the points of zero magnetic declination on the earth's surface, that is places at which the needle of the compass points due north and south The plane of the *magnetic meridian* of a place, which is the vertical plane passing through the two poles of a magnetic needle freely suspended at that place, does not in general coincide with that of the geographical meridian, a vertical plane passing through the place, and the north and south terrestrial poles The angle between these planes is the *magnetic declination* But at certain places these planes do coincide, and such places are called places of *no declination* The line which joins all these places is called the *line of no declination* or *agonic line* A line of this kind passes through the east of South America to Hudson's Bay, thence through the North Pole to the White Sea, passing southward it cuts Arabia, and then after traversing the Indian Ocean and the eastern portion of Australia, goes through the South Pole to join itself again (See *Magnetism, Terrestrial*)

AIR See *Atmosphere*

AIR GUN A pneumatic instrument which will drive a bullet by means of compressed air It consists of a gun barrel communicating with a hollow ball, into which air is forced by means of a condenser A bullet is put into the barrel, and the valve which confines the compressed air opened, the air then expands and forces out the bullet According to Boyle's Law, the force of the expanding air is proportional to the pressure A pressure of 500 atmospheres has been attained by means of a powerful condenser, but this is only about half the elastic force of fired gunpowder

AIR PUMP Since the pressure of the atmosphere may be considered to be about 15lbs on the square inch, it follows that if we have a cylinder closed at one end and open at the other, and have an air tight piston on the bottom of the cylinder, we shall require (neglecting friction and the weight of the piston) to exert a force as many times 15lbs as the surface of the piston contains square inches, in order to overcome the pressure of the air and to move the piston Between the piston and the bottom of the cylinder, there will then be formed a vacuum If this vacuum be put in communication with a vessel full of ordinary air, that is, air which has been compressed by the atmospheric pressure, and which is therefore in the condition of a compressed spring, this air will spread itself out so as to occupy the vacuous space in addition to the original volume of the vessel, in other words, it will become uniformly diminished in density, and its new density will be to its original density inversely as its new volume is to its original volume If now the piston be pushed back, the air will resume its original volume and density when the piston reaches the bottom of the cylinder But if communication be interrupted between the cylinder and the vessel when the piston is at the top of the cylinder, the air beneath the piston will be compressed as the piston descends, until it acquires the ordinary atmospheric tension Let us suppose that the piston is provided with a valve A opening upwards (towards the air), and the connecting tube between the cylinder and the vessel which is being exhausted, has a valve B opening into the former Whenever the piston is pulled up, its valve A is closed by the atmospheric pressure, while the valve B is opened by the elastic force of the air in the vessel When the piston is pushed down, the valve B closes by the elastic force of the air beneath the piston, and at a certain part of the stroke, namely, when the tensions of the atmosphere above and the air below are equal, the valve A commences to open so that the air escapes Accordingly, at every up-stroke the density of the air in the vessel diminishes according to the relative capacities of it, and of the cylinder The valves in the air pump are usually made of oiled silk stretched over holes, so that the force required to lift them is very small It is usual also to have two cylinders and pistons connected by racket and cog-wheels, so that when one is ascending the other is descending The vessel from which the air is withdrawn is called the *receiver* For many experiments it has the form of a strong bell jar, the edge of which is ground quite flat, and rests upon a flat glass or brass plate, into the centre of which the tube connecting it with the cylinder opens In connection with this connecting tube is a long straight tube dipping into mercury The height to which the mercury is raised is a measure of the completeness of the exhaustion. It is a matter of course that the exhaustion effected by such a machine is never quite perfect, depending as it does upon successive distension.

AIR PUMP, SPRENGEL'S. See *Sprengel Pump*.

AIR THERMOMETER. The air thermometer is an instrument which consists of a vessel containing a volume of air shut off from communication with the external air by a column of liquid contained in a tube of small bore, which tube is open at one end, and connected at the other with the vessel containing the inclosed air. The first thermometer (see article *Thermometer*) was an air thermometer, and many modifications have been since devised. The air thermometers employed by Gay Lussac for determining the co-efficient of expansion of air, consisted of a capillary tube terminated by a glass bulb; the latter contained a known volume of perfectly dry air, shut off from the external air by a short column of mercury in the capillary tube, which served as an index. When the bulb was heated the air within it expanded, its pressure was consequently greater than that of the external air, and the mercury in the capillary tube was forced further from the bulb; a reverse effect took place on cooling the bulb. With such thermometers, a correction must always be made for atmospheric pressure, as, unlike mercurial thermometers, they are open to the air. Regnault has compared the air with the mercurial thermometer, with the following results:—

Temperature given by the Air-Thermometer.	Temperature given by the Mercurial Thermometer.
100° C.	100° 00
120	119 95
140	139 85
160	159 74
180	179 63
200	199 70
240	239 90
260	260 20
280	280 52
300	301 08
340	343 00
350	354 00

From this we see that the agreement is tolerably close up to 260° C.; beyond which, to the boiling point of mercury (350° determined by the air thermometer), the divergence increases.

Regnault has measured the high temperatures of furnaces, by heating a weighed flask of platinum or porcelain containing mercury, in the furnace the temperature of which is to be ascertained. The mercury boils and expels all the air from the flask, which is then filled with the vapour of mercury at the temperature of the furnace; it is now closed, withdrawn from the furnace, cooled, and weighed. The various data now at command enable the temperature to be determined; the volume of the flask is known, the weight of the vapour of mercury which filled it at the temperature of the furnace, and the density of that vapour. Deville and Troost have employed the vapour of iodine for the same purpose. (See also *Thermometer*, *Differential Thermometer*, *Expansion*, *Pyrometer*.)

ALABASTER. See *Sulphates, Calcium*.

ALBIREO. (Arabic.) A star in the head of Cygnus. It is a well-known and very beautiful double star easily resolved. The primary is orange, the smaller star blue.

ALBUMEN. (*Albumen*, the white of an egg.) A substance occurring largely in the animal kingdom, and to a less extent in the vegetable kingdom. Its chief sources are white of egg, and the serum of blood; it exists in two forms, soluble and insoluble; soluble albumen in the dry state is a pale yellow gummy-looking mass, tasteless and inodorous, of specific gravity, 1 26. It dissolves in water containing an alkaline salt, and when this solution is heated to 60° C. (140° F.), the albumen passes into the insoluble form, and is precipitated as a white mass. After coagulation, albumen is white, translucent, and brittle, when dry; and opaque and elastic, in the presence of water. Soluble albumen is coagulated by many acids. It acts chemically like a weak acid, and forms compounds with bases which are called albuminates; the form in which it exists in white of egg is that of albuminate of sodium. The albumen extracted from vegetable bodies is called vegetable albumen, although it appears to be identical with animal albumen; it occurs principally in the seed. The composition of albumen is not well ascertained; the most probable formula is $C_{72}H_{112}N_{18}SO_{22}$.

ALCOR. (Arabic.) Flamstead's star 80 of the constellation Ursa Major. It forms a wide naked-eye double with the star Mizar, the middle star of the tail, from which it is separated by a distance equal to about half the moon's apparent diameter. (See *Mizar*.)

ALCOHOL. By this name, when standing by itself, is usually understood the second term of the series of ordinary alcohols, or vinic alcohol. (See *Alcohols*.) It is a transparent, colourless, mobile liquid, of a specific gravity, 0 7939 at 60° F.; it boils at 74 4° C. (173 1° F.); its vapour

density is 1 613, its formula is C_2H_6O, it is the spirituous principle of wine, beer, and spirits, and is produced by the fermentation of sugar, which is split up into alcohol and carbonic acid. In the diluted state, alcohol is sometimes called spirits of wine It is difficult to render anhydrous, distillation alone will not produce an alcohol containing less than 9 per cent. of water, and this remaining quantity must be removed by adding something which unites with the water chemically, such as quick lime By oxidation it is converted into aldehyd, and then into acetic acid, but other products of oxidation are obtained in less quantity, these are formic acid, acetal, acetic ether, saccharic acid, glyoxal, glyoxylic acid and glycollic acid, the final products being water and carbonic acid When the elements of water are removed from absolute alcohol, ether is formed (which see)

ALCOHOL PHENYLIC See *Carbolic Acid*

ALCOHOLS, SERIES OF Ordinary alcohol is the second term of a series of homologous bodies which differ from one another in composition by CH_2, and exhibit a regular gradation of properties, physical and chemical They are divided into monatomic, diatomic, and triatomic alcohols, according as they are built upon the type of one, two, or three molecules of water. The principal monatomic alcohols at present known are—

Methylic alcohol,	CH_4O.
Ethylic alcohol,	C_2H_6O.
Propylic alcohol,	C_3H_8O.
Butylic alcohol,	$C_4H_{10}O$.
Amylic alcohol,	$C_5H_{12}O$.
Caproylic alcohol,	$C_6H_{14}O$.
Œnanthylic alcohol,	$C_7H_{16}O$.
Caprylic alcohol,	$C_8H_{18}O$
Cetylic alcohol,	$C_{16}H_{34}O$.
Cerotylic alcohol,	$C_{27}H_{56}O$.
Melissic alcohol,	$C_{30}H_{62}O$

There are four diatomic alcohols known. These are called Glycols They are as follows —

Ethylene glycol,	$C_2H_6O_2$.
Propylene glycol,	$C_3H_8O_2$
Butylene glycol,	$C_4H_{10}O_2$.
Amylene glycol,	$C_5H_{12}O_2$

The triatomic alcohols are called glycerins One term only is known, namely ordinary glycerin, $C_3H_8O_3$ In addition to these alcohols there are many other series thus, we have (to give one instance only of each series) Allyl alcohol, C_3H_6O; Camphol, $C_{10}H_{18}O$, Benzyl alcohol, C_7H_8O, Phenyl alcohol (or Carbolic acid), C_6H_6O, Cinnamic alcohol, $C_9H_{10}O$, Saligenin, $C_7H_8O_2$

ALCYONE (Greek) The brightest of the star group called the Pleiades

ALDEHYD A liquid obtained by the removal of two atoms of hydrogen from alcohol, whence its name, *alcohol dehydrogenatus* It is a thin transparent colourless liquid, of a strong suffocating odour, it boils at 21° C (69 5° F), it mixes in all proportions with water, alcohol, and ether, its formula is C_2H_4O It forms numerous compounds, amongst which the following may be mentioned—aldehyd-ammonia, $C_2H_4ONH_3$, formed by passing ammonia into aldehyd and ether It exists as transparent, white, colourless crystals, very brilliant, melting at about 75° C (167° F), and distilling at 100° C (212° F) Acids separate aldehyd from it Sulphite of aldehyd-ammonia is a white crystalline body, soluble in water and alcohol, formed by mixing sulphurous acid with aldehyd ammonia The characteristic reactions of the homologous series of the aldehydes are the formation of definite compounds with the acid sulphites of alkali metals, and the reduction of silver salts to the metallic state.

ALDEBARAN (Arabic) The chief star of the constellation Taurus, a red star.

ALDERAMIN (Arabic) The star α of the constellation Cepheus

ALEMBIC (Arabic, *al*, the, *ambeeq*, corrupted from ἄμβιξ, a cup) A piece of chemical apparatus somewhat like a glass retort, but having the head and neck removable from the body Alembics were formerly much used, but are now generally superseded by retorts, except in some manufacturing processes

ALFONSINE TABLES Astronomical tables, published under the auspices of Alfonso X, king of Castile and Leon, in 1252.

ALGEIBA. (Arabic) The star γ of the constellation Leo. It is a fine double, a good test for small telescopes. The components are orange and green.

ALGENIB (Arabic) The star γ of the constellation Pegasus It forms one of a remarkable square of stars, called by astronomers "the square of Pegasus," the other three stars forming the square being α and β Pegasi, and α Andromeda (otherwise called respectively, Markab, Scheat, and Alpheratz)

ALGOL (Arabic) The star β in the constellation Perseus A remarkable variable (See *Stars, Variable*)

ALHENA (Arabic) The star γ of the constellation Gemini

ALIDADE (Arabic) A rod carrying the sights of a quadrant, and serving to indicate how many degrees or minutes the observed object is raised above the horizon The term is obsolete

ALIOTH (Arabic) The star ϵ of the constellation Ursa Major

ALIZARINE The colouring matter of Madder It is a brilliant scarlet substance which crystallises in prisms, and when exposed to carefully regulated heat sublimes, condensing into beautiful tufts of scarlet needles It is only sparingly soluble in water, but dissolves in spirit and in alkaline solutions Its tinctorial power is at least thirty five times as great as that of madder itself Turkey red, madder pink, and all the finer madder colours are compounds of alizarine and fatty acids with bases The discovery of the method of preparing alizarine artificially is due to two continental chemists, Messrs Graebe and Liebermann, and is the result of a scientific investigation on the properties and molecular structure of alizarine, conducted step by step in accordance with logical deductions from the known laws of synthetical chemistry The formula of alizarine is $C_{14}H_8O_4$ From an examination of the substances obtained when alizarine was submitted to certain chemical operations, it had been ascertained that it is connected with the hydro carbon group, containing $C_{14}H_{10}$, and by heating it with zinc dust the above-named chemists actually obtained from it the hydro carbon $C_{14}H_{10}$ This was seen to be identical with one of the solid crystalline bodies obtained in the distillation of coal, named anthracene, and by a somewhat complicated process they converted this into anthraquinone, then into bibrom anthraquinone, and lastly into alizarine, having by this means added O_4 and removed H_2 from the anthracene (See *Madder*)

ALKAID (Arabic) The star η of the constellation Ursa Major It is the last star of the three which form the Bear's tail

ALKALAMIDES See *Amides*

ALKALI (Arabic, *al Kali*) A name applied to a well defined class of bodies characterised by the following properties They turn red litmus paper blue, completely neutralise acids, they are soluble in water, and their solutions exert a caustic action upon animal matter The alkalies proper are the oxides of potassium, sodium, lithium, rubidium, and cæsium To these must be added the compound alkali ammonia, the oxide of the hypothetical metal ammonium, which used to be called the volatile alkali, in contradistinction to potash and soda, which were called fixed alkalies The alkaline earths are the oxides of barium, strontium, calcium, and magnesium The oxides of some other metals, such as silver, thallium, and lead, are also somewhat soluble in water, and possess slight alkaline properties

ALKALIMETRY The method of estimating the amount of alkali in alkaline liquids It is usually effected by the volumetric process of analysis, by ascertaining how many divisions of a graduated tube containing an acid of definite strength are required to neutralise the liquid under examination

ALKALINE SPECTRA The spectra produced by the metals of the alkalies and alkaline earths are readily seen by introducing one of their compounds into a spirit flame, and examining the flame by a spectroscope. The flame will then become coloured crimson with lithium, yellow with sodium, purple with potassium, deep red with rubidium, bluish with cæsium, brick red with calcium, red with strontium, and green with barium Each of these coloured flames gives a spectrum of bright lines peculiar to itself, and sufficiently characteristic to be used as a chemical test (See *Spectrum*, *Spectrum Analysis*, *Spectra of the Metallic Elements*)

ALKALOID (Alkali, and εἶδος, a resemblance) A name given to a very numerous and important class of organic substances, which, possessing many of the properties of the alkalies of the mineral kingdom, are termed alkaloids Some of them, hydrate of tetrethylium for instance, rival potash and soda in their alkaline properties Some alkaloids are obtained exclusively from the vegetable kingdom, where they frequently constitute the active principle of the plant, for instance morphia, quinine, and strychnine, some correspond in composition to ammonia, and are produced artificially from it by replacement (See *Amides*) As a specimen of these, we may mention methylethylamylophenylammonium Others in which the nitrogen is replaced by other elements of the same group, such as phosphorus, arsenic, antimony, or bismuth are prepared artificially Amongst these may be mentioned arsenethylium, and triethyphosphine The most important alkaloids will be described under their respective headings

ALKES (Arabic) The star α of the constellation Crater It was probably the brightest star of the constellation when Bayer so lettered it, but is now far less conspicuous than δ.

ALKARSIN. See *Arsenic*

ALLOTROPY Inorganic solids occur under one of three conditions, viz —(1) The *crystalline*, as the diamond, (2) the *vitreous*, as glass or barley-sugar, and (3) the *amorphous*, or shapeless, as clay, chalk, &c But there are many bodies, any one of which, without undergoing a change in chemical composition, may yet appear under one of the above three conditions, with striking changes in physical and even chemical properties, while still retaining, so to speak, its chemical identity Sulphur, for example, sometimes occurs in native octohedral *crystals*, or it may be obtained in the *crystalline* form by evaporation from one of its solutions These crystals, which are hard and brittle, may be fused by the application of heat, and if the melted sulphur be poured into cold water it becomes tough, flexible, and translucent, it may be kneaded and also drawn into threads It is now in the *vitreous* condition, and it does not take fire so readily as ordinary sulphur By exposure to the air for a few days it becomes brittle, opaque, and partly crystalline, and if treated with the liquid solvent, bisulphide of carbon, the crystalline portion dissolves, leaving a buff-coloured insoluble powder This is *amorphous* sulphur If this be exposed to the action of heat it recovers its solubility These three forms of sulphur differ in density and specific heat

The term *allotropy* (from ἀλλος, another, and τροπος, habit,) has been applied to the branch of science which takes account of the different sets of properties, possible to one and the same body Although the science of the subject is obscure, yet it seems to point to the fact that bodies possessing very different properties may be composed of the same ultimate atoms, and that in the wise economy of nature the mode of arrangement of the atoms is as important as the elementary nature of the atoms themselves

Notable examples of allotropy occur in the case of phosphorus, which may be crystalline, vitreous, or amorphous, soluble or insoluble, inflammable or non inflammable at moderate temperatures, waxy and translucent, or of an opaque, dull, brick red colour, and so on. Carbon may also exist in the form of the diamond, graphite, charcoal, &c Compound bodies, among other changes, may vary in colour, as in the case of sulphide of mercury, which may be either of a black or of a scarlet colour Glass, which is the type of vitreous bodies, may become opaque, and semi-crystalline Even gases are subject to allotropic conditions, *ozone* and oxygen being two such states of the same body

ALLOXAN One of the numerous products of the oxidation of uric acid It forms large transparent colourless crystals, readily soluble in water or alcohol, in the anhydrous state the formula is $C_4H_2N_2O_4$ It is decomposed by heat, and also by most reagents Hydrochloric and sulphuric acids or reducing agents convert alloxan into *alloxantin*, which under the action of ammonia is converted into purpurate of ammonium or murexide (See *Murexide*) The formula of alloxantin is $C_8H_4N_4O_7\ 3H_2O$

ALLOXANTIN See *Alloxan*

ALLOYS Combinations of metals with each other are called alloys, except when mercury is a constituent, in which case they are called *amalgams*. The following are the most important alloys —

NAME OF ALLOY	COMPOSITION
Aluminium bronze,	Copper and aluminium.
Bell metal,	Copper and tin
Bronze,	Copper and tin.
Gun metal,	Copper and tin.
Speculum metal,	Copper and tin.
Brass,	Copper and zinc.
Dutch gold,	Copper and zinc
Mosaic gold,	Copper and zinc.
Ormolu,	Copper and zinc.
Tombac,	Copper and zinc
German silver,	Copper, nickel, and zinc.
Packfong,	Copper and arsenic
Britannia metal,	Tin and antimony.
Solder,	Tin and lead
Pewter (ordinary),	Tin and lead
Fusible metal,	Bismuth, lead, tin, and cadmium
Type metal,	Lead and antimony (and sometimes a little copper)
Stereotype metal,	Lead, antimony, and bismuth.

Shot metal, . . .	Lead and arsenic.
Standard gold, . .	Gold and copper
Standard silver, .	Silver and copper

In the preparation of alloys the least fusible metal should be melted first, and the most fusible added in small quantities at a time A flux, such as borax, chloride of zinc, or tallow, (according to the temperature), being added to prevent loss by oxidation The fusing point of alloys is generally lower than the mean of the fusing points of the constituent metals Alloys are generally more tenacious, but less malleable and ductile, than would be expected from their composition

ALLYL (*Allium*, garlic) The oil of garlic contains both the sulphide and the oxide of allyl Allyl is a very volatile liquid, possessing a specific gravity of 0 684, and a boiling point of 138° F (59° C) Formula C_3H_5 Allyl was isolated by Berthelot and De Luca in 1856

ALLYL ALCOHOL An organic liquid, one of the series of alcohols (See *Alcohols*) It is of interest owing to some compounds of its radical allyl being identical with the oils of mustard and garlic They are as follows —*Sulphide of allyl*, $C_6H_{10}S$, a colourless, highly refracting oil, lighter than water, and boiling at 140° C (284° F) It is identical in composition and properties with oil of garlic *Sulphocyanate of allyl*, C_4H_5NS, a transparent, colourless oil, having in a very high degree the sharp penetrating odour of mustard It blisters the skin, and possesses in every respect the properties of the essential oil extracted from black mustard

ALMACH (Arabic) A bright star on one of the feet of Andromeda

ALMAGEST (Compounded of the Arabic, *al*, the, and the Greek μέγιστον, greatest) The name given by Arabic astronomers to the celebrated treatise on astronomy by Ptolemy

ALMONDS, OIL OF BITTER This oil is produced by the action of emulsin on the amygdalin contained in bitter almonds It consists chiefly of hydride of benzoyl, together with hydrocyanic acid, benzoic acids, benzoin and benzimide Hydride of benzoyl, or pure oil of bitter almonds, is a colourless strongly refracting liquid, with a peculiar smell and burning taste It boils at 79° C (354° F) It is not poisonous when pure, the ordinary oil of bitter almonds owing this property to the hydrocyanic acid which it contains It is regarded as the aldehyd of the benzoic group Its composition is C_7H_6O

ALNILAM (Arabic) The star ε of the constellation Orion It is the middle star of Orion's belt, and a somewhat remarkable object, being involved in nebulous light It is also variable

ALPHARD (Arabic) The star α of the constellation Hydra In the sea snake's body The star is also called *Cor Hydræ*

ALPHECCA (Arabic) The leading star of the constellation Corona Borealis It has been called "the gem of the crown"

ALPHERATZ (Arabic) A bright star in the head of Andromeda, but also represented in ancient charts as appertaining to the constellation Pegasus It is, in fact, according to Bayer's nomenclature, at once α Andromedæ, and δ Persei (See *Algenib*)

ALPHIRK (Arabic) A star in Cepheus

ALSHAIN. (Arabic) The star β of the constellation Aquila

ALTAIR (Arabic) The leading star of the constellation Aquila.

ALTITUDE (*Altitudo*, height) In astronomy, the angular distance of a heavenly body from the horizon, measured in the direction of a great circle passing through the object and the point overhead

ALTITUDE AND AZIMUTH INSTRUMENT, or sometimes the *Alt Azimuth* A telescope so constructed as to be moveable primarily about a vertical axis, and secondarily, about a horizontal axis, at right angles to the tube of the telescope Such a telescope may be directed towards a celestial object by two movements Thus, suppose the telescope directed in the first instance horizontally, towards the north, and that the object to be observed lies towards the south-west, and at an elevation of forty-five degrees Then the telescope must first be turned about the vertical axis towards the west and through an angle of 135 degrees, then on the horizontal axis upwards and through an angle of 45 degrees The former angle is called the *azimuth* of the object (see *Azimuth*), the latter its *altitude* (see *Altitude*), and the instrument derives its name from the fact that it is brought to bear on objects by motions affecting these relations For scientific purposes, the alt azimuth has not been much used The altitude and azimuth of every celestial object are continually changing, so that an object can only be kept in the field of an alt-azimuth by a continual and variable process of double motion, which no machinery can impart The alt-azimuth has, however, been used at Greenwich for determining the elevation of the moon when due east or west

ALUM (*Alumen*) Under this name are included many salts which are formed upon the same type—that of common alum $AlK(SO_4)_2\ 12H_2O$ The Al (aluminium) in this may be replaced by the similar metal chromium, or iron, and the K (potassium) by the similar metallic group—ammonium (NH_4), or the metals silver, cæsium, &c The following alums may be described —*Double Sulphate of Aluminium and Potassium* ($AlK(SO_4)_2\ 12H_2O$) —This is prepared in large quantities for use in the art and manufactures It crystallises very readily in large colourless octahedral crystals, which are tolerably soluble in water, and slightly efflorescent in the air *Double Sulphate of Aluminium and Ammonium* ($Al(NH_4)(SO_4)_2\ 12H_2O$), or Ammonia alum —This is very similar to potash alum, and is used indiscriminately with the latter in the arts, as the commercial value of alums depend on the alumina and not on the other base Commercial alum is frequently a mixture of ammonia and potash alum *Chrome Alum* —Under this head are known double sulphates of chromium, with sulphate of ammonium or sulphate of potassium The one best known is the potassic Chrome alum ($CrK(SO_4)_2\ 12H_2O$), it crystallises in large octahedrons, which have a splendid ruby red colour, and are tolerably soluble in water

ALUMINA See *Aluminium*

ALUMINIUM The metallic basis of alumina, which, in combination with silica, is the chief constituent of clay The metal itself is difficult to prepare, but of late years it has become an article of commerce, and may be obtained at a reasonable price It is a white metal, unalterable in the air, and capable of taking a fine polish, it is very malleable and ductile, and somewhat soft after fusion, but is rendered hard by hammering Its specific gravity is 2 56, it melts a little above the fusing point of zinc, and may be cast with readiness It is very sonorous, emitting a clear bell like sound, when a bar is suspended by threads and struck with a piece of wood Its electric conductivity is about equal to that of silver, and it is an excellent conductor of heat Owing to its unalterability in the air, and non attack by sulphuretted hydrogen, aluminium ornaments retain their brilliancy in the atmosphere of towns, in which silver would tarnish rapidly Aluminium is not attacked by nitric acid, dilute sulphuric acid, or vegetable acids, but hydrochloric acid and caustic alkaline solutions dissolve it readily The atomic weight of aluminium is 27 5, and its symbol Al The principal compounds are as follows —

Chloride of Aluminium ($AlCl_3$) This compound is prepared by heating a mixture of alumina and carbon in a current of dry chlorine gas, it sublimes at a moderate heat, condensing to a transparent waxy substance, it is very deliquescent, and its solution in water on evaporation yields a hydrated chloride in crystals Chloride of aluminium unites with chloride of sodium to form a double salt, which is permanent in the air, and only slightly deliquescent This compound is the one by means of which the metal is prepared When sodium is heated with it, the whole of the aluminium it contains is reduced to the metallic state

Alumina —This is the only known oxide of aluminium, its formula is Al_2O_3 It is a white insoluble powder in the anhydrous state, and after strong ignition it is almost insoluble in acids Its specific gravity varies between 3 72 and 4 0 In the native state it occurs crystalline, and according to its colour and transparency, is known under the name of emery, corundum, sapphire, ruby, oriental topaz, and oriental amethyst At the temperature of the oxyhydrogen flame, alumina fuses, and if chromate of potassium is added to it, the fused mass on cooling has a ruby colour like the natural gem Alumina forms several hydrates when precipitated from solutions, it unites with acids to form salts, the most important of which will be described under the headings of the respective acids

ALWAID (Arabic) The star β Draconis, one of the eyes of the monster, according to the maps

AMALGAMATED ZINC If a plate of common commercial zinc be placed in dilute sulphuric acid, it is quickly dissolved in the acid, sulphate of zinc being formed if, however, the zinc plate be amalgamated, that is, cleaned by immersion in acid and then rubbed over with mercury, so as to present a bright surface, it may be placed in the acid without being attacked This property has not been satisfactorily accounted for, but it is of great importance, for it was pointed out by Mr Kemp of Edinburgh, in 1826, that the zinc, on being amalgamated, loses none of its power as one of the metals of a voltaic couple On placing a copper plate in the same acid, and making contact between the two plates, the solution of the zinc at once commences, hydrogen is given off from the copper plate, and an electric current is produced If the connection is broken, the action on the zinc at once stops Since, therefore, the zinc is only wasted when the current is passing, amalgamated zinc is now used in all voltaic arrangements

AMALGAM, ELECTRIC, (ἅμα, together, γαμεώ, to unite,) is made by rubbing together in a mortar 1 part of tin, 2 of zinc, and 6 of mercury Or the zinc and tin may be melted together, and poured into a wooden box containing the mercury. The box is then closed, and smartly shaken till cold. The powder produced in either of these ways is mixed with a little grease or lard.

The amalgam is used for smearing the silk with which glass is rubbed in obtaining electricity by friction, particularly in the case of the rubbers of the electric machine. It is found that its application very much increases the quantity of electricity obtained. No satisfactory explanation has been given of its action. Probably part of the effect is due to the perfect discharging of the rubber, which would be effected by thus giving it a metallic coating.

AMALGAMS. See *Alloys*.

AMBER. (Arab. *Anbar*.) A fossil gum found in certain geological formations, and sometimes thrown up on the sea-shore. It is hard, brittle, and tasteless, insoluble in water and alcohol, but soluble in sulphuric acid and in alkalis. The specific gravity varies between 1.065 and 1.070. Amber is susceptible of polish, is generally semi-transparent, and when submitted to friction, becomes highly electrical. When subjected to destructive distillation, amber yields succinic acid, water, oil, and an inflammable gas.

AMBERGRIS. A substance formed in the intestines of the spermaceti whale, and sometimes cast upon the sea-shore. It is a gray brittle solid, possessing a peculiar odour. Specific gravity, 0.780 to 0.926.

AMETHYST. (αμεθυστος,—α, not, and μεθυω, to be drunk.) A gem so named from its supposed property of preventing drunkenness. The common amethyst is simply a coloured crystal of quartz, and is much inferior in value to the oriental amethyst, which consists of crystallised alumina. (See *Corundum*.)

AMIANTHUS. See *Asbestos*.

AMIDES. A term used to express a compound ammonia, in which one, two, or three of the hydrogen atoms are replaced by an acid radical. The nomenclature of this subject was very confused, until Gerhardt and Chiozza (Ann. Ch. Phys. (3) xlvi.), proposed certain simplifications, which are now generally adopted. Ammonias, in which one or more atoms of hydrogen are replaced by an acid radical, are called *amides*, thus we have acetamide, &c. Ammonias, in which one or more atoms of hydrogen are replaced by base radicals, are called *amines*, thus we have potassamine, ethylamine. Ammonias, in which two or more atoms of hydrogen are replaced by acid and base radicals, are called *alkalamides*, thus we have ethylacetamide. Further, these three classes are divided into *monamides*, *diamides*, and *triamides*, *monamines*, *diamines*, and *triamines*, *monalkalamides*, *dialkalamides*, and *trialkalamides*, according as they are derived from one, two, or three molecules of ammonia.

AMINES. See *Amides*.

AMMONIA, or, *Volatile Alkali*. A colourless gas of a powerful odour and taste, its specific gravity is 0.5893, it neither supports combustion nor respiration, it is feebly combustible, and has the same action upon vegetable colours as caustic potash, the effect, however, being evanescent. By a cold of −40° C. (−40° F.), or by a pressure of six atmospheres, at a temperature of about 50° F. ammoniacal gas is condensed to a liquid, in which state it is colourless and very mobile, of the specific gravity, 0.76, and boiling at −33.7° C. (−28.75° F.). By exposing the dry gas to a pressure of 20 atmospheres, and at the same time to a cold of −75° C., Faraday obtained solid ammonia as a white transparent crystalline body. Ammoniacal gas has the formula NH_3, it is greedily soluble in water, with evolution of heat, and great expansion, forming aqueous ammonia, or solution of hydrated oxide of ammonium. One volume of cold water absorbs 670 volumes of ammonia, or nearly half its weight, forming a solution of specific gravity 0.875. When fully saturated, the specific gravity and boiling point vary according to the amount of ammonia dissolved in the water. A perfectly saturated solution has a specific gravity of 0.85 and a boiling point of −4° C. (25° F.). A solution of specific gravity 0.87 boils at 10° C., one of 0.90 specific gravity boils at 30° C., one of 0.93 specific gravity boils at 50° C., one of 0.96 specific gravity boils at 70° C., whilst one of specific gravity 0.99 boils at 92° C. Aqueous ammonia dissolves many oxides and salts which are insoluble in water, such as oxide of copper, chloride of silver, &c., it precipitates most of the heavy and earthy metals from their acid solutions, in the form of hydrates or oxides, and on this account is a most valuable test in chemical analysis. By exchanging one, two, or three of its atoms of hydrogen successively for a metal, or for a compound radical, the important class of *amides* is formed. (See *Amides*.) Ammonia unites with acids to form salts, which, in their chemical composition, are identical with those of potassium or sodium salts, if we consider that the metal in the compound is replaced by the group NH_4 ammonium. The most important ammoniacal salts, which are not described below, are given under the headings of the respective acids.

AMMONIUM. A hypothetical metal, which is assumed to exist in ammoniacal salts, its formula is NH_4. By adopting this theory, which was first proposed by Berzelius, ammoniacal salts are brought into chemical analogy with potassium and sodium salts, which they resemble almost perfectly. This theory has derived a singular confirmation in the discovery of an amalgam of ammonium, which may be obtained, like amalgam of potassium, by

the action of a strong galvanic battery on a solution of ammonia, the negative pole being formed of mercury The mercury increases largely in volume, and assumes the consistence of butter, and, when fully saturated, floats upon water At 0° C it solidifies and crystallises in cubes At the ordinary temperature this amalgam quickly decomposes into ammonia and hydrogen and liquid mercury The same amalgam may be prepared by bringing sodium amalgam into contact with a strong and warm solution of chloride of ammonium, the reaction takes place rapidly, and the buttery amalgam, after being rapidly dried, may be preserved for a considerable time in castor oil

AMMONIUM, CHLORIDE OF Known also as *Sal Ammoniac* A compound of ammonium and chlorine, analogous to chloride of sodium and chloride of potassium Its formula is NH_4Cl It is a white crystalline substance, readily soluble in water, less so in alcohol, volatilised by heat without previous fusion It is decomposed by heating with slaked lime, when gaseous ammonia, NH_3, is given off

AMMONIUM, SULPHIDE OF The pure sulphide NH_4S, forms colourless crystals which are volatile at the ordinary temperature The aqueous solution is frequently employed in the laboratory as a test, it is generally prepared by passing sulphuretted hydrogen to saturation into an aqueous solution of ammonia Sulphide of ammonium dissolves excess of sulphur, and forms a yellow liquid which consists of a mixture of several higher sulphides, such as the di sulphide $(NH_4)_2S_2$, the tri-sulphide, $(NH_4)_2S_3$, the tetra-sulphide $(NH_4)_2S_4$, &c

AMORPHISM (*a*, without, *μορφη*, form) Solids are either crystalline or amorphous, the *vitreous* condition noticed under *Allotropy*, being a variety of Amorphism An amorphous body has no crystalline structure, no planes of cleavage, so that it can be broken equally well by applying force in any direction, the fracture is not granular, but conchoidal The same body may often occur crystalline or amorphous, and it is generally heavier, harder, and less soluble in the crystalline than in the amorphous state The passage of a body from the amorphous to the crystalline state is called *transformation*, and from the crystalline to the amorphous state *deformation* If a solution be cooled too rapidly, the solid is apt to become amorphous, when, under other conditions, it would be crystalline

An amorphous body may be produced (1) by *fusion* or *vitrification*, of which glass, many slags, obsidian, pumice stone, &c, are examples, (2) by *evaporation* of a solution, as in the case of gum, glue, white of egg, &c (3) by *precipitation*, as in the case of most voluminous, gelatinous, and viscid matters, thrown down from solutions

Some examples of amorphism are given under the heading *Allotropy*, and they might be multiplied to any extent In some cases, considerable light is thrown upon structure, and difference in property depending thereon, by considering whether the body has been deposited in a crystalline or an amorphous form Quartz, for example, has a specific gravity of 2 652, it refracts light doubly, is slightly soluble in a boiling solution of potash, and does not harden when brought into contact with lime and water Opal (which, like quartz consists of silica,) has a specific gravity of 2 09, it refracts light singly, dissolves readily in a boiling solution of caustic potash, and hardens into a mortar with lime and water These striking differences seem to arise from opal being amorphous, while quartz is crystalline silica Opal also contains combined water, which, being driven off by heat, leaves the silica nearly as soluble in potash as it was before There are many phenomena pertaining to arsenious acid, which seem to show that the atoms are sometimes in the amorphous, and at other times in the crystalline order Sugar and barley-sugar afford other examples

AMPÈRE'S RULE Under this name is known a rule which Ampère has given, by which the direction of deflection of a magnetic needle, under the influence of a current passing in its vicinity, may be determined or remembered (See *Electro-dynamics*) The following is the rule — "Imagine an observer placed in the wire which conducts the current, so that the current shall pass through him, from his feet to his head, and let him turn his face toward the needle, the north pole is always deflected to his left side" The law may be verified by comparison with the following table, showing the direction of the current, and the effect of it upon the needle —

CURRENT ABOVE NEEDLE		CURRENT BELOW NEEDLE	
Direction of Current	Deflection of North Pole	Direction of Current	Deflection of North Pole
S to N	W	S to N	E
N to S	E	N to S	W

AMPÈRE'S THEORY OF MAGNETISM Led by the resemblance between the action of magnets upon each other and upon currents, and the mutual action of solenoids, Ampère proposed a theory of magnetism, according to which all magnetic phenomena are brought under the laws of electro-dynamics He supposes closed electric currents to circulate around the elementary molecules of all magnetic substances In the unmagnetised condition of the body these currents flow in all directions with respect to each other, and to the mass of matter, but when the body is magnetised, they are all turned round in such a way that the planes in which they flow are parallel to each other, and perpendicular to the line joining the poles of the magnet Further, he supposes the currents to circulate in the direction of the hands of a watch to an observer looking from south to north A little consideration will show that the effect of the currents passing round a molecule in the interior of the magnet upon external bodies is null, it being neutralised by the effects of the currents circulating about the molecules which surround it, but at the exterior of the magnet there will be a general resultant, consisting of parallel currents circulating round the magnet, and these will give rise to attraction and repulsion precisely as do the currents in a solenoid (See *Electro dynamics*, *Solenoid*)

AMPHID SALT See *Haloid*

AMPLITUDE In astronomy, the distance of a celestial object at rising or setting from the east or west points of the horizon respectively

AMPLITUDE OF VIBRATION (*Amplitudo* (amplus), extent) In sound, the amplitude of the vibration of a point on a sonorous body is the greatest distance between two positions of the point Thus, if a horizontal string vibrate in a vertical plane without the formation of nodes (see *Nodes*), all the points of the string will travel upwards and downwards together The amplitude of each particle's vibration is the distance from its highest to its lowest position It is clear that the central point of the string will traverse the longest path (the amplitude of its vibration will be the greatest), and that this path will be a straight line The paths of each pair of points on each side of the central point will be equal and similar, but less than that of the central one But little error is involved in considering the string to have the shape of a circular arc in all its positions, the radius of the circle increasing as the string approaches the straight line (its original position), when the radius of its curvature is infinite Each point may also be assumed to have a straight path when the vibration is not great in comparison with the length of the string Compared with surface waves (see *Waves in liquids*), or undulations, the vibration of a string presents this difference In the liquid, all the particles of the surface enjoy in succession the same amount of "excursion," the amplitude of the motion of each is the same, this is, as we have just seen, not the case with the vibrating string

The amplitude of the motion of a particle of the medium through which a sonorous wave passes, is, in like manner, the distance between its extreme positions—that is, the point which it occupies when its immediate neighbours and itself are in a state of maximum compression, and when they are again in the state of maximum condensation (See *Propagation of Sound*) For as the sonorous wave passes along, each particle of the medium oscillates backwards and forwards, and if the points of the sonorous body vibrate in straight lines, which is not always the case (see *Colour of Sound*), so also will the particles of the medium Whatever be the actual shape of the path described by a particle, the amplitude of its vibration is considered as the distance between its extreme positions, whether the body be a sonorous arc or a vibrating medium

AMYGDALIN The crystalline principle of bitter almonds, laurel leaves, &c It forms white scales of a pearly lustre very soluble in water, its composition is $C_{20}H_{27}NO_{11}\ 3H_2O$ It is the source of bitter-almond oil and hydrocyanic acid, into which and glucose it splits under the influence of emulsin, a ferment which exists with it in the plant, and commences to act when made into a paste with water

AMYL (ἄμυλον, starch) A colourless liquid hydrocarbon, isolated by Frankland in 1849. Its formula is C_5H_{11}, boiling point, 311° F (155° C), vapour density, 4 90, specific gravity at 32° F 0 7413 Amyl exists in an impure state in potato fousel oil, and is also formed during the destructive distillation of coal

ANALOGOUS POLE A term used in describing the phenomena of pyro electricity Certain crystals while being heated exhibit electric polarity, one end assuming the positive state, and the other the negative While cooling, the polarity changes, the end which during the heating became positive now becoming negative, and *vice versa* (See *Pyro electricity*) The end which becomes positive as the temperature increases, and negative while it decreases, is called the *analogous* pole, the end which becomes negative while the temperature increases, and positive while it decreases, is the *antilogous* pole The names are, however, but little used

ANALYSER The Nicol prism, slice of tourmaline, or crystal of herapathite, which is placed

next the eye in a polariscope, and serves to analyse the beam which has passed through the polariser and doubly refracting substance (See *Polariscope*, *Polariser*, *Polarised Light*)

ANALYSIS, CHEMICAL (ἀνα, back or up, λυσις, a loosening or releasing) Chemical analysis is the resolving of a compound body into its constituent parts, whether it be merely the purpose of discovering what the constituents of it are, in which case it is called *qualitative* analysis, or for the purpose of determining also in what proportion they occur, when it is called *quantitative* analysis The description, even in the briefest possible manner, of the method of performing analyses would be, of course, far beyond our limits All that we can do here is to give the most general statement of the objects of analysis, and an indication of what means are adopted for the fulfilling of these objects, and to mention the sources from which the reader may, as far as books are concerned, obtain detailed information The actual performance of analysis requires considerable chemical knowledge, especially minute knowledge of certain properties of bodies, their forms, their behaviour in presence of certain other bodies, their solubility, both absolute and relative in various liquids, their comportment in presence of heat and flame, and so forth, and besides this skill in manipulation, in the application of tests, or *re-agents*, as they are called, and very frequently in fitting up apparatus If the analysis be of any but the most simple and straightforward kind, a skill that can only be gained by considerable laboratory practice will be absolutely necessary for its accomplishment The reader will find information regarding the methods employed in Faraday's *Chemical Manipulation* and in the text books to be mentioned immediately

There are various objects with which an analysis may be undertaken, and there are therefore various ways in which it may be accomplished For example, in one case it may be necessary with regard to a given specimen to name every constituent that occurs in it, as in the analysis of an unknown mineral, in another, the question may simply be, Is a certain body here, or is it not? which frequently happens in cases of medical chemistry Then there is mineral analysis, and the analysis of commercial products, there is the examination of water and the like, and there is the analysis of organic bodies, which may itself be divided into an enormous number of different kinds, and it is the business of the analyst to understand the various methods, and to apply one or more which shall accomplish his object with a degree of accuracy depending upon the importance of the inquiry, and with a proper regard to the time at his disposal

When the problem is one belonging to qualitative analysis, it is generally solved in one of two ways, or by a combination of the two It is well known that heat and especially flame, produce very remarkable changes in the appearance and properties of many bodies, these changes are very definite and depend only on the nature of the flame and of the substance to which it is applied, and a knowledge of this, and the application of the "flame tests," as they are called, very often gives with great rapidity the knowledge required The other principal way may roughly be said to be that of the application of liquid tests The body is by some means got into solution in some known liquid, and then other liquids called tests or re-agents are added to the solution thus made The mixing together of these liquids is intended to produce a precipitation of a solid substance in the liquid, a change of colour, an effervescence of gas or some other phenomenon which can readily be detected by sight, smell, or taste, and the comparison of the result with what we should expect from previous knowledge to take place if some supposed body were present, indicate to us whether it is so or not Of these methods there are, as we have said, numberless variations, in fact, they are altered more or less with every fresh case Very great help is now derived in qualitative analysis, particularly in difficult cases, or cases where a minute trace of a body is to be detected, by the use of the spectroscope By means of it very remarkable discoveries have lately been made, and the advantage of its aid is being felt daily more and more (See *Spectroscope*, *Spectrum Analysis*)

In quantitative analysis, where the object is not only to know what bodies are present, but to know the proportions in which they are associated, two great methods are adopted, which are known by the names of analysis by weight, and volumetric analysis The general principle of the first is to combine the elements one after another by precipitation with some other elements or groups, and thus to form insoluble compounds These precipitates are collected and weighed, and by calculation from the results obtained it is easy to deduce the numbers required (See *Affinity*, *Atomic Weight*) The other method is frequently used when it is only required to know the quantity of some one body present in the known weight of a given specimen It will perhaps be best understood by an example Suppose it were required to find the quantity of alkali in 100 grains of a rough commercial product A solution of it is made, and a small quantity of litmus, which is blue in presence of free alkali, but red in presence of free acid (see *Litmus*), is added A solution of acid is then made of standard strength, as it is called, that is, a solution containing in every cubic inch a certain known quantity of acid, and this is gradually

mixed with the solution to be tested The acid combines with the alkali and forms a salt, and the greater the quantity of alkali present the greater the quantity of the acid solution required in order to satisfy it As long as there is an excess of alkali the litmus remains blue, but the moment the acid predominates the litmus turns red, and by noting the quantity of standard acid solution added, the amount of alkali in the 100 grains of the given compound is readily calculated Volumetric analysis is carried on by means of such processes as that described

For further information we refer our readers to Fresenius's Handbooks of Analysis, Qualitative and Quantitative, to Miller's Elements of Chemistry, Watt's Dictionary of Chemistry, and for details of special processes on this vast subject, we can do no more than suggest the Journal of the Chemical Society

ANALYSIS, SPECTRUM See *Spectrum Analysis*

ANAMORPHOSES (ανα, again, and μορφωσις, a form) A distorted drawing which appears at first sight confused and unintelligible, but which from the proper point of view appears correctly drawn

ANATASE See *Titanium, Dioxide*

ANDROMEDA One of Ptolemy's northern constellations It is represented in the maps under the figure of a woman chained by the hands and feet This constellation includes several remarkable objects, amongst which may be mentioned specially the triple star Gamma Andromedæ, and the wonderful nebula 31 Messier, compared by its discoverer, Simon Mayer, to the light of a horn lantern This nebula is chiefly remarkable for its great size and brightness, and the great difficulty which astronomers have experienced in resolving it into discrete points of light It has been so resolved, however, and Mr Huggins has discovered that the spectrum of the nebula resembles that of the fixed stars, but with a somewhat sudden diminution of light towards the red extremity

ANEMOMETER (ἄνεμος, wind, and μέτρον, measure) An instrument for measuring the velocity or force of the wind

Robinson's Anemometer, called also the *Hemispherical-cup Anemometer*, is one of the best for measuring the velocity of the wind Four hemispherical cups are affixed to the ends of two horizontal cross rods, forming a square cross The cross rods are supported in a horizontal position on a vertical axis, about which they can turn freely The cups being so attached that the circular rim of each is in a vertical plane through the supporting pole, and the convexity of each towards the concavity of the next, it is clear that in whatever direction the wind may be blowing horizontally, the cups will "catch the wind" and the cross rods rotate An endless screw on the vertical rod communicates motion to a series of index-wheels, and thus the number of miles traversed by the wind in any given time can readily be noted The instrument is tested by being conveyed at considerable speed for a given distance and back again, on a calm day, its indications being compared with the distance actually traversed

By suitable contrivances this instrument may be made to indicate the varying velocity of the wind, as well as the average velocity in a given time, but the machinery for the purpose is complicated and expensive

Lind's Anemometer is intended to indicate the actual pressure exerted by the wind on a surface of given size A tube bent into the form of the letter U is placed with both legs vertical and the bent part of the tube downwards, one leg, which reaches higher than the other is bent near the top, at a right angle The whole instrument is half filled with water, and being so suspended as to turn freely on a horizontal axis, a vane attached to the tube causes it always to turn the open end of the bent leg in the direction from which the wind is blowing Thus the wind blows into the bent tube, and by its pressure on the surface of the water within the instrument, causes the level to fall in the bent tube and to rise proportionately in the other A scale attached to the unbent tube indicates the difference between the two levels, or, in other words, the height of a column of water capable of counterpoising the pressure of the wind

This instrument may also be used to indicate the maximum pressure of the wind during any interval, by using instead of water a chemical solution capable of colouring pieces of paper attached at different levels within the unbent tube

Whewell and Casella have also devised instruments for registering the direction and velocity of the wind

ANEMOMETRY. The art of measuring the force or velocity of the wind (See *Anemometer*)

ANEMOSCOPE (ἄνεμος, wind, and σκοπέω, to view) An instrument for indicating the direction of the wind An ordinary vane is an anemoscope, but the term is commonly limited to appliances by which the direction of the wind is indicated to an observer placed where the wind is not felt

ANEROID BAROMETER. See *Barometer, Aneroid.*

ANGELINA. An asteroid discovered by M Tempel, at Marseilles, on March 4th, 1861 The name refers to the astronomical station at Notre Dame des Anges, near Marseilles

ANGLE OF LEAST DEVIATION If a ray of homogeneous light is allowed to pass through a prism it will be bent from its straight path By gently rotating the prism on its axis the emergent beam will be found to be bent in different degrees from its original path The position of the prism when the beam is least bent from a straight path is called the position of least deviation, and the angle formed by it with the incident ray of light is called the angle of least deviation (See *Prism, Spectroscope*)

ANGLE OF POLARISATION See *Polarising Angle*

ANGLE OF REPOSE The greatest angle with the horizontal at which a given inclined plane can support a given body at rest, called also limiting angle of resistance (See *Inclined Plane, Friction*)

ANGLESITE See *Sulphates, Lead*

ANGULAR VELOCITY The angular velocity of one body about another is the rate at which a line, continually drawn from the former to the latter, shifts its direction in space

ANHYDRIDES (α, without, ὕδωρ, water) Chemical compounds, when they are free from water, are said to be *anhydrous*, and are often spoken of as *anhydrides* Thus H_2SO_4 is the composition of sulphuric acid, by removing the elements of water, H_2O, we obtain SO_3, which is sulphuric anhydride There are also organic anhydrides, such as benzoic anhydride, and ethionic anhydride Salts, when free from their water of crystallisation, are termed *anhydrous salts*, as opposed to hydrated salts

ANHYDRITE See *Sulphates, Calcium*

ANHYDROUS SALTS See *Anhydrides*

ANILINE A transparent colourless oily liquid, having a somewhat pleasant odour and aromatic burning taste, it is slightly soluble in water, forming a faintly alkaline solution, it is miscible in all proportions with alcohol, ether, sulphide of carbon, and fixed and volatile oils, its specific gravity is 1 02, it boils at 182° C (360° F), it is inflammable, burning with a bright smoky flame, its formula is C_6H_7N, it has been described in chemical works under the names of Phenylamine, Crystalline, Kyanol, Benzidam, and Phenamide Aniline is supposed to be derived from ammonia (NH_3), by the replacement of one of the hydrogen atoms by phenyl C_6H_5 It is, therefore, a phenyl monamine, and may be called monophenylamine Aniline, which a few years ago was a substance of scientific interest only, is now prepared by hundreds of tons for the manufacture of its coloured derivatives, known as the aniline dyes These will be described under their chemical names in the following paragraphs Aniline is a powerful base and saturates acids, forming salts, which are generally highly crystalline Amongst its salts may be mentioned—*Hydrochlorate of Aniline*, very soluble needle shaped crystals, *Nitrate of Aniline* crystallising in concentric needles, *Oxalate of Aniline*, which crystallises in stellate groups of oblique prisms, which are only slightly soluble in cold water

The substitution derivatives of aniline are of the highest complexity, owing to its containing so many atoms which may be replaced by other bodies It would require an elaborate treatise on organic chemistry to render the formation of these compounds sufficiently intelligible, we shall, therefore, simply select the most important of them, without attempting to enter into details respecting their relationships

Mauvine This is a nearly black crystalline body It is an organic base, having the composition $C_{27}H_{24}N_4$, it unites with acids, forming salts, which constitute the well known aniline purple or mauve The substance originally prepared by Perkin is the sulphate of this base, it forms small crystals having a strong green metallic lustre, dissolving in water forming a purple solution, and having intense tinctorial powers

Rosaniline, or Aniline Red, known also as roseine, fuchsine, azaleine, magenta, &c An organic base crystallising in white needles, capable of uniting with acids to form salts These salts form the colouring matter of commerce The formula of rosaniline is $C_{20}H_{19}N_3$ The acetate of rosaniline separates in magnificent crystals, sometimes an inch in diameter, and possessing a brilliant green metallic lustre, they are very soluble in water, and form a deep red solution Hydrochlorate of rosaniline crystallises in large rhombic plates, slightly soluble in water The nitrate crystallises in needles. The salts usually met with in commerce for dyeing purposes are the acetate, hydrochlorate, and nitrate Silk and wool dipped into aqueous solutions of either of these salts withdraw them from solution, and become dyed of a beautiful rose-red colour Cotton, on the other hand, does not withraw this colouring mater, but must be first treated with a mordant of some animal substance, such as albumen

Tri-ethylrosaniline $(C_{20}H_{16}(C_2H_5)_3N_3)$ This is formed by replacing three of the atoms of hydrogen in rosaniline by the same number of atoms of the radical ethyl. Its salts are of a

rich violet colour, and are used as a dye for silk and wool, being known in commerce as Hofmann's violet, after the discoverer

Triphenyl-rosaniline ($C_{20}H_{16}(C_6H_5)_3N_3$) This base is formed in a similar manner to the one last described, the radical phenyl being substituted for ethyl The salts of this base are blue, diphenyl-rosaniline giving bluish violet salts, and monophenyl rosaniline giving violet salts By introducing the radical tolyl (by employing an aniline containing toluidine) mono- di- and tri- tolyl rosanilines are obtained, which resemble in colour the corresponding phenyl compounds The pure salts of triphenyl rosaniline are known in commerce, as night blue, or *bleu lumière* Triphenyl rosaniline forms a conjugate acid with sulphuric acid, which is very soluble even in cold water this is known in commerce as soluble blue When it is remembered that several atoms of hydrogen in rosaniline can each be replaced by methyl, ethyl, amyl, phenyl, tolyl, and a hundred other similar radicals, and that each of the resulting compounds possesses tinctorial powers, it will be readily understood that the aniline dyes of this class are almost as numerous as the experimentalists who have worked on the subject Moreover, as the technical processes of making these dyes were found out usually long before the scientific explanation, or chemical formula, of the colouring matter was established, it will scarcely be wondered at that litigation has been so frequently associated with this branch of industry

Aniline Green is another colouring matter produced from the substitution action on rosaniline There are several aniline greens, but their chemical composition has not yet been definitely settled

Chrysaniline ($C_{20}H_{17}N_3$) This is an amorphous yellow substance, almost insoluble in water, but readily soluble in alcohol, forming a rich orange solution, which dyes silk and wool of a splendid golden yellow colour Chrysaniline is a weak base, forming crystalline salts with acids Besides these dyes of well-defined composition, others have been prepared of a black, brown, primrose, orange, and other colours, but their chemical history not having yet been satisfactorily made out, their description belongs more to the domain of technology than to that of pure science

ANIMAL HEAT The human body possesses an invariable temperature of about 98 6° F, though the surrounding atmosphere may have a far lower temperature Thus the temperature of the blood of a Greenlander is practically the same as that of an inhabitant of Ecuador or India There is an internal source of heat in all organised beings, and it is due to chemical action, in the form of oxidation The various products of food are oxidised in the lungs, the carbon becomes carbonic acid gas the hydrogen becomes water, and the heat produced by the chemical combination—that is, by the clashing together of the combining molecules—serves to keep the blood at an uniform temperature The lungs have been often called the furnace of the body, while the carbon and other oxidisable constituents of venous blood are the fuel, and the inspired air yields the oxygen necessary for the combustion The inhabitants of cold countries consume a far larger quantity of carbonaceous food than those of more southern climes, because they require a larger amount of heat to preserve their blood at a temperature of 98 6° F, and hence a larger amount of bodily fuel (See *Respiration*) In certain diseases the temperature of the blood exceeds 98 6°, but even in very severe cases of fever the excess is not more than 3 6° F

Birds possess the highest temperature, and, as we should expect, they also evolve a far larger amount of carbonic acid in a given volume of expired air than other animals The blood of mammalia comes next in order as regards temperature, then that of amphibia, fishes, and insects, while crustacea and worms possess the lowest temperature of all, as may be seen from the following table .—

TEMPERATURE OF THE BLOOD OF VARIOUS ANIMALS

Name	Temperature of the air	Temperature of the blood	Name	Temperature of the air	Temperature of the blood
Chicken,	77° F.	111° F	Bat, .	82° F.	100° F
Pigeon,	78	109 5	Porpoise, .	72	100
Sparrow,	80	108	Elephant, .	80	99·5
Jackdaw,	85	107	Horse, .	80	99 5
Hog, .	75	105	Man, .	79	98 6
Sheep, .	78	104 5	Serpents,	81 5	88 5
Monkey,	86	104 5	Testudo midas,	79 5	84 0
Elk, .	78	103	Oyster,	82	82
Ox, .	80	102	Crayfish, .	80	79
Cat, .	79	102	Shark, . .	71 75	77
Rat, .	80	102	Snail,	76 25	76
Jackal, .	84	101	Glowworm, .	73	74

The temperature of the blood is usually determined by placing a very delicate and sensitive thermometer under the tongue

M Radau (La Chaleur, p 98), in speaking of the disengagement of heat by plants, says, "Dans une jeune tige, dans les racines, les bourgeons, les fleurs, les fruits, des combinaisons chimiques ont lieu, qui ont pour effet le développement des organes, ces combinaisons ne sont pas très-énergiques, mais elles sont néanmoins accompagnées d'un faible dégagement de chaleur" He instances the fact that the spathe of the common arum at the time of flowering possesses a temperature of 7° C (12 6° F) above that of the surrounding air, while, in the Isle of France, the *arum cordifolium* has an excess of temperature of 30° C (54° F), which may be readily shown by placing a thermometer in the centre of the flower

ANIMAL NUTRITION The animal body may be regarded as a machine which has to perform certain work, including voluntary movement of the limbs, involuntary movement, such as that of the heart and lungs and the circulation of the blood, brain work, either animal or intellectual, besides which the temperature has to withstand a constant drain upon it from radiation and evaporation In addition to all this, the natural wear and tear of the body, the growth of certain parts, and (up to maturity) the increase of bulk of all portions have to be supplied In order to supply this constant drain upon its resources, a constant influx of material is necessary in the form of food If this is appropriate, a considerable amount of the available force which it represents is made use of, but if inappropriate, there is waste of material and also loss of power in getting rid of the useless material Many circumstances should be considered in viewing the subject of animal nutrition in its complete form Thus the income represented by food goes through certain chemical changes, and the expenditure assumes certain forms Part goes off as heat, muscular movement, brain force, and growth, whilst another portion is occupied in doing the chemical work required to convert the dead food into living tissue In the present article it is proposed only to consider the chemical work performed The animal body is not capable of assimilating mineral matter direct, this work has to be done by the vegetable world, and when it has been vitalised in this manner, the animal can take it and raise it a step higher in the scale If an animal eat vegetable food, it has to perform the work of raising the vegetable matter to its own level, but if animal food be eaten, this work is already done, and it only requires assimilation Food nearly always consists of the elements carbon, oxygen, hydrogen, and nitrogen, and also certain mineral ingredients, phosphorus, sulphur, chlorine, fluorine, potassium, sodium, calcium, iron, silicon The available force of the body, in whatever form it appears, is produced by the union of some of these substances with oxygen, and it is necessary that they are presented in such a form as to be easily assimilated or digested. There are several classes of food, all of which should be present in a normal diet,—these are, 1, albuminous, protein, and other compounds containing nitrogen, 2, fatty matters, consisting chiefly of hydrocarbons, 3, carbohydrates, such as starch and sugar, 4, water and mineral constituents It was for a long time thought that the first class serve to repair waste and to assist growth, whilst the fatty matters and carbohydrates serve to supply animal heat, but recent researches have proved that this is a fallacy, and that some of the muscular force and heat is derived from the oxidation of the nitrogenous matter, although its chief function is to repair tissue The function of the fatty portion of food is principally to supply heat, it also serves important functions in the processes of digestion, assimilation, and nutrition The digestive power of fat is considerable, and it is no less active in the conversion of the nutrient constituents of food into the solid substrata of organs Fat is also the form in which surplus food, if assimilable, is stored up in the body as a reserve, it accumulates round certain organs, and gives rotundity to the form, whilst by its bad conducting power, it retains animal warmth The class of carbohydrates contain oxygen and hydrogen in the proportion to form water, their carbon alone being capable of oxidation, they also form lactic, butyric, and other acids, which appear to be necessary, and they are likewise concerned in the production of fat The mineral constituents act as carriers, and in other ways non-chemically The first operation which food must undergo in the body is digestion In the stomach it is brought into contact with special solvents, such as the gastric juice, the pancreatic fluid, the bile, &c, by which it is thoroughly deprived of its nutritive qualities, which are carried into the circulation Digestion, indeed, as Berzelius remarked, is a true process of rinsing, the amount of fluid secreted into the alimentary canal, and again absorbed from it, being not less than 3 gallons daily, the greater part consisting of the gastric juice, the active principle of which is *pepsin*; that of the pancreatic fluid being called *pancreatin* Having been absorbed into the circulation, a considerable amount of oxidation goes forward in the lungs, by means of which organs, air and blood are brought into intimate contact, carbon and hydrogen in the blood, uniting with the oxygen of the air, and being exhaled as carbonic acid and water, both of which are readily detected in the breath Other products of oxidation are found in the urine and fæces. (See *Food, Functions of, Muscular Power, Urea, Uric acid; Hippuric acid, Creatinine*)

ANIONS (ἀνιών, that which goes up), are substances which, during electro-chemical decomposition, go to the *anode* They are equivalent to *electro-negative* bodies or substances which go to the *positive pole*, according to less strict phraseology. This, and the name *Kathions* (κατιών, that which goes down), signifying the substances which go to the *Kathode*, were given by Faraday (Exp Research ser vii), in order to get rid of the terms *electro-positive* and *electro-negative*, which imply a theory (See *Anode*) The anions are oxygen, chlorine, and bodies which correspond to them, including the compound bodies called the acid radicals Thus water is decomposed into oxygen and hydrogen, of which the former is the *anion*, and appears at the anode, and the latter the *kathion*, and is found at the kathode (See *Kathion*, and for further information, *Electrolyte* and *Electrolysis*)

ANNULAR ECLIPSE An eclipse of the sun, in which the moon is wholly projected on the sun's disc, but, having a less apparent diameter, a ring of light from the outer parts of the sun's disc remains still visible (See *Eclipse*)

ANODE (ἄνω, upwards, and ὁδός, a way, the way which the sun rises), is a term made use of in speaking of the phenomena of electrolytic decomposition It denotes the surface at which the current, according to the common phraseology, enters the *electrolyte* or body undergoing decomposition Oxygen, chlorine, and acids are evolved there It is opposite to the kathode, or surface at which the current leaves the electrolyte The terms *anode* and *kathode* (κατα, downwards, and ὁδός, a way) were applied by Faraday (Experimental Researches, ser vii) to prevent confusion, and distinguish these surfaces from the *electrodes* of the battery with which they are in contact He compares the direction of the current with that of a current round the earth supposing it to be an electro-magnet, which, according to the present usage of speech, must be from east to west, or with the apparent motion of the sun Supposing, then, that a current passes through the electrolyte parallel to the current round the earth, the *anode* is the eastern, and the *kathode* is the western surface of it Thus, whatever changes may take place in our ideas of electrical action, and of the direction of the electric current, must, he says, affect equally both the hypothetical current round the earth and the current through the electrolyte, and we shall be saved from any confusion attending such a chance (See *Electrolysis*, *Electrolyte*)

ANOMALISTIC (See *Anomaly*) The anomalistic period of a planet or satellite is its time of revolution from apse to apse If the line of apsides were constant in position, the anomalistic period would be the same as the sidereal period, but as in all cases the line of apsides slowly varies in position, the anomalistic period has a different value For further illustration see *Year, Anomalistic*

ANOMALY (α, not, and ὁμαλος, even) An angle used for convenience of calculation in dealing with the motion of a celestial body in an elliptic orbit There are three kinds of anomaly the *eccentric*, the *mean*, and the *true* If a circle be described on the transverse diameter of the ellipse as diameter, and a perpendicular be drawn to the transverse axis through the place of the celestial body, then a line drawn from the centre of the ellipse to the point in which this perpendicular produced meets the circle, includes with the transverse diameter the angle called the *eccentric anomaly*, this angle being measured from that part of the transverse axis which passes through the centre of attraction The *mean anomaly* is the angle which the body would have described around the centre of the above-named circle, if, instead of moving with varying velocity in its elliptic orbit, it had travelled with its mean angular velocity around the circle The *true anomaly* is the angular distance actually traversed by the body around the centre of attraction In all three cases the body is supposed to start from that extremity of the transverse axis which lies nearest to the centre of attraction

ANSÆ (*Ansa*, a handle) A term sometimes applied to the apparent projections formed by Saturn's rings on each side of the planet

ANTARCTIC (ἀνταρκτικός, opposite to the arctic) In astronomy the term antarctic is given to that part of the heavens which includes the South Pole It is so named because it lies opposite to the arctic pole (See *Arctic*) The *Antarctic circle* is rather a geographical than an astronomical expression But the position of this circle on the earth is indicated by the astronomical relations, that within its limits the sun, during the summer solstice of the southern hemisphere, does not set, while along this circle (neglecting refraction) the sun's centre just touches the horizon at midnight, at the summer solstice of the southern hemisphere

ANTARES (Arabic) The chief star of the constellation Scorpio Remarkable for the singular fulness of its ruddy tint (See *Scorpio*)

ANTHRACEN, or, *Pardnaphthaline* A hydrocarbon, obtained from the heavier portions of the tar produced in the dry distillation of wood and coal It forms small colourless plates, which melt at about 213° C (415° F) to a colourless liquid, and distils at a temperature above 300° C (572° F) It is insoluble in water, but easily so in hot alcohol,

ether, and benzol The composition of anthracen is $C_{14}H_{10}$, it is now of considerable importance, as it is the starting point in the manufacture of artificial alizarin

ANTILOGOUS POLE Opposite of analogous pole, *q v*. The terms are used in describing the phenomena of pyro electricity

ANTIMONIURETTED HYDROGEN See *Antimony*

ANTIMONY A metallic element first discovered by Basil Valentine Its symbol is Sb, from its Latin name *Stibium*, and its atomic weight 120 3 In the pure state it has a brilliant bluish white colour, and is highly crystalline It is very brittle, and is easily reduced to powder It melts at 450° C (842° F), and at a white heat volatilises Its specific gravity varies between 6 7 and 6 86 By electrolysis Mr Gore has prepared amorphous antimony, which has the colour and appearance of polished steel and a specific gravity of 5 78, this when heated or struck suddenly becomes very hot and changes throughout its mass to ordinary crystalline antimony Antimony is permanent in the air at the ordinary temperature, but oxidises when melted, and takes fire at a red heat Nitric acid oxidises it to the tri- or pent oxide, but does not dissolve it Sulphuric and hydrochloric acids attack it with difficulty Antimony forms three definite oxides, the *tri oxide*, the *tetroxide*, and the *pent oxide* The tri oxide or *antimonious oxide* (Sb_2O_3) is sometimes found native It is formed when antimony burns in the air, when it is deposited in shining prismatic crystals known as flowers of antimony It may be prepared in the wet way by precipitation It is sparingly soluble in water, more freely so in acids With bi tartrate of potassium it forms a double salt known as tartar emetic (See *Tartaric acid*) The tetroxide of antimony is of little importance, it is found native as antimony ochre Its formula is Sb_2O_4, and is supposed to be a mixture of the tri- and pent- oxides Pent-oxide of antimony, also called *antimonic oxide* and *antimonic acid*, (Sb_2O_5) is a white powder sparingly soluble in water, soluble in hydrochloric acid and in caustic alkalies It is produced by oxidising antimony to the fullest extent with nitric acid It exists in two states, as antimonic acid which is monobasic; and metantimonic acid which is di basic They each form definite salts with bases The following are the only compounds which need be mentioned —Antimoniate of lead, a basic salt, is used in oil-painting under the name of Naples yellow Acid metantimoniate of potassium ($K_2O\,Sb_2O_5 + 7\,H_2O$) This salt forms a crystalline mass readily soluble in warm water, but soon decomposing It is used in laboratories as a test for soda, as when a freshly prepared solution is added to a sodium salt a precipitate of insoluble acid metantimoniate of sodium is produced When this test is employed with proper precautions it is exceedingly delicate, so it will detect a sodium salt when present in more than a thousand times its weight of water

Oxychloride of Antimony, formerly called Powder of Algaroth, a heavy white amorphous powder of variable composition, but containing chloride of antimony and tri oxide of antimony, formed by the action of water on oxychloride of antimony

Sulphides of Antimony The tri sulphide, Sb_2S_3, occurs native as stibnite, gray antimony, antimony-glance, &c It is largely employed as a source of antimony, and when purified from the gangue by fusion it is known in commerce as *crude antimony* The native or artificially fused sulphide crystallises in prisms, it cleaves very readily; specific gravity 4 62, hardness = 2, it is easily cut and is slightly flexible, it has a lead gray metallic lustre, and is easily fusible The tri-sulphide in the amorphous state prepared artificially is sometimes known as mineral kermes, it is a brown red, loosely coherent powder The hydrated tri-sulphide of antimony is of a dark orange red colour precipitated when sulphuretted hydrogen is passed through an acid solution of the tri-oxide or the tri chloride

Hydride of Antimony, or *Antimoniuretted Hydrogen* (SbH_3) A colourless, transparent, and inodorous gas, formed when nascent hydrogen is generated in a solution containing antimony, or when an alloy of antimony and zinc is dissolved in acids It is insoluble in water, when passed through a glass tube, and strongly heated, it is decomposed with separation of metallic antimony When passed into a solution of nitrate of silver it forms a black precipitate of antimonide of silver Antimoniuretted hydrogen is liable in analysis to be mistaken for arsenuretted hydrogen, and *vice versa* For distinctive characteristics special works on analysis must be consulted

Tri chloride of Antimony, sometimes called Butter of Antimony A translucent, fatty looking mass, melting at 72° C (162° F) and boiling at 200° C (392° F) Its composition is $Sb\,Cl_3$ It fumes in the air Water decomposes it into hydrochloric acid and oxychloride of antimony or powder of algaroth Hydrochloric acid dissolves it without precipitation

Pentachloride of Antimony A colourless, very volatile liquid, formed when metallic antimony and chlorine unite The combination takes place with brilliant combustion when the powdered metal is thrown into chlorine It gives up two of its chlorine atoms to other substances very readily, and is thus of great use in some chemical reactions Its formula is $Sb\,Cl_5$.

Pentasulphide of Antimony A yellowish red powder, formed when sulphuretted hydrogen is passed through a solution containing the pentachloride or the pentoxide, its formula is Sb_2S_5 It unites in the capacity of an acid with other metallic sulphides, which act as base, to form sulphantimoniates The alkaline sulphantimoniates are soluble in water and crystallise readily, their composition is 3 M_2S SbS_5, the letter M representing the metal

Antimony is capable of combining with alcohol radicals forming compounds, some of which may be regarded as ammonia (NH_3), in which the nitrogen is replaced by antimony and the hydrogen by three equivalents of the radical As an illustration we need only mention one of these, triethylstibine ($Sb(C_2H_5)_3$) The constitution of other organic compounds of antimony is not so clearly made out

ANTLIA. In astronomy (abbreviated from *Antlia Pneumatica*, the air pump), a southern constellation formed by Lacaille

APHELION. (ἀπό, from, and ἥλιος, the sun) That point in the orbit of any member of the solar system which lies farthest from the sun

APLANATIC (ἀ, without, and πλάνη, error) A name used in optics to denote a lens so constructed as to be free from spherical aberration (See *Aberration, Spherical*)

APOGEE (ἀπό, from, and γῆ, the earth) That point of the moon's orbit which lies nearest to the earth The term is sometimes, but incorrectly, applied to the planets Its use with reference to the sun is scarcely more legitimate, though of course recognised as just when the earth was regarded as the centre of the universe

APOMORPHIA. (ἀπό, from, and *morphia*) An organic base discovered by Dr Matthiessen and Mr Wright It is prepared by the action of hydrochloric acid on morphia at a high temperature The physiological effects of apomorphia are those of a non irritant emetic and powerful anti stimulant, the action, however, rapidly passing off, leaving no after ill effects, it will probably come into use in medicine (See Proc R S, vol xvii, p 455) The composition of apomorphia is $C_{17}H_{17}NO_2$

APPARENT (*Appareo*, to appear) A term of frequent use in astronomy, to indicate the position or motions of celestial objects as they appear to the eye as distinguished from their real motions in space

APPARENT SOLAR DAY The interval between two successive transits of the sun across the meridian of any place (See *Day*)

APPROACH CAUSED BY VIBRATION See *Vibration, Approach caused by*

APPULSE (*Appulsus*, an arrival) In astronomy the near apparent approach of one celestial body towards another The term is chiefly applied to stars or planets near to which the moon passes, without occulting them

APSE See *Apsis*

APSIDES, LINE OF (ἁψίς, the felloe of a wheel) The imaginary line joining the apses of the orbit of a planet or satellite Or, more strictly, it is the line joining what would be the apses of the planet's path if the planet were to move undisturbed through a complete revolution, from the moment considered

APSIS, or, *Apse* (See *Apsides, Line of*) The point of the orbit of a planet or satellite at which it is farthest from or nearest to the sun or primary, respectively or, more correctly, the points of such orbits at which the direction of motion is at right angles to the line from the centre of motion

APUS In astronomy, (α, without, and πούς, a foot), the bird of Paradise, a southern constellation formed by Bayer.

AQUAFORTIS See *Nitric Acid.*

AQUAREGIA See *Nitric Acid*

AQUARIUS (The water-bearer) A Zodiacal sign, the eleventh in order The sun enters this sign about the 20th of January, and leaves it about the 19th of February The Zodiacal constellation Aquarius now occupies the region corresponding to the sign Pisces A remarkable feature in this constellation is the existence of two well marked star streams within its limits, with prolongations extending over the constellations Grus and Piscis Australis

AQUILA In astronomy (the eagle), one of Ptolemy's northern constellations In ancient star maps the figure of the boy Antinous is placed in company with the eagle, and Tycho Brahe framed the stars belonging to the figure of Antinous into a separate constellation, which is not now recognised, however, by astronomers The Milky Way presents some singularly rich protuberances within the limits of Aquila It is indeed well worthy of notice that whereas in Cygnus the branch which extends towards Ophiuchus is far the brightest, the branch extending towards Aquila grows rapidly brighter from Vulpecula southwards, the portion which crosses the southern half of Aquila being absolutely the brightest visible in our northern heavens

ARA In astronomy (the altar), one of Ptolemy's southern constellations. According to

Aratus the Centaur was conceived by ancient astronomers as in the act of placing an offering on the altar, but by a strange mistake the altar is represented in all modern star maps in an inverted position It seems not improbable that the ancient astronomers recognised in the strangely complex parts of the Milky Way which lie to the north of this constellation some resemblance to smoke from an altar

AQUEOUS HUMOUR That portion of the transparent contents of the eye which lies between the *cornea* and the *iris* (See *Eye*)

ARABIN The name given by Newbauer to a gummy substance obtained from Gum Arabic by treatment with hydro chloric acid and alcohol He considers that it has the property of an acid, and that it exists in Gum Arabic in combination with lime and magnesia Its composition is $C_{12}H_{22}O_{11}$, when freshly prepared it dissolves in cold water, but after drying it merely swells up to a gelatinous mass

ARAGO'S PHOTOMETER Arago has described (*Œuvres completes de Francois Arago*, vol x) a photometer of complicated construction founded on the law of the square of the cosines, according to which polarised rays pass from the ordinary to the extraordinary image His description, however, is not clear in the original, and would be quite unintelligible without woodcuts (See *Photometry*)

ARCH (*Arcus*, a bow) A structure of stones or bricks placed in the form of a bow, so as to support one another by their mutual pressure The separate wedge-shaped stones of the arch are termed *voussoirs* or ring-courses, and the centre one is called the *key stone* The pillars on which the extremities of the arch rest are the abutments, and their upper courses the *impost* or *springing courses* The distance between the tops of the abutments is the span of the arch, a straight line joining the tops, the *spring line* The internal concave surface of the arch is termed the *soffit* or *intrados*, the upper surface of the ring of arch stones is sometimes called the *extrados*, sometimes, however, this term is applied to the solid masonry or backing above them A wall standing on an arch is termed a *spandril-wall* The problem "to find the arch of greatest strength" is usually a very difficult one The arch of greatest strength, on the supposition that there is no superincumbent pressure, is shown by the theory of pressures to be a catenary, or a curve precisely similar to that formed by a flexible string when suspended from two fixed points (See *Catenary*) The determination of the form of greatest strength of a loaded arch from the principles of stability and strength is an almost impracticable problem from its complexity It will depend upon the weight of the materials forming the load, and the manner in which the pressures are transmitted

The *Hydrostatic Arch* is an arch suited for sustaining normal pressure at each point proportional, like that of a liquid at rest, to the depth below a given horizontal plane The radius of curvature at any point of the arch is inversely proportional to the pressure, and also inversely proportional to the depth below a horizontal plane, such that vertical lines from it represent the intensity of the pressure A mechanical mode of drawing a hydrostatic arch is furnished by the fact, that its figure is the same as that presented by an elastic spring when bent

The *Geostatic Arch*, or, as it is sometimes called, the transformed hydrostatic arch, is a curve such that the vertical pressure is proportional to the depth below a fixed horizonal plane, and the horizontal pressure bears to the vertical pressure a fixed ratio depending on the nature of the superincumbent materials This arch is suited to sustain the pressure of earth It may be drawn by constructing first the figure of the hydrostatic arch, and transforming it by keeping the vertical co-ordinates the same, but altering the horizontal co-ordinates into lengths changed according to the constant ratio

The condition of equilibrium of an arch is determined by the position of the line of pressures. If a straight line be drawn at each bed-joint (the joint between two arch-stones) in the direction of the resultant pressure at that joint, all the lines thus drawn will form a polygon, termed the line of pressures The curve through the angular points of the polygon is the *equivalent linear arch* Now in order that the stability of the arch may be secure, there should be no tendency to open the joints either above or below, and this is the case if the centre of pressure of each joint be not more than a sixth of its length from the centre, that is, "if the equivalent linear arch fall within the middle third of the depth of the arch ring"

Skew Arches are arches derived from symmetrical arches by distortion in a horizontal plane For further information consult *Manual of Applied Mathematics* by Professor Rankine Papers by M. Yvon-Villarceaux in the *Mémoires des Savans etrangers*, vol xii Tredgold on *Masonry* (Encyc Brit) Gauthey, *Traité de la Construction de Ponts* (See *Bridges*)

ARCHIMEDEAN SCREW One of the earliest machines used for lifting water It consists of a cylinder inclined to the vertical, either exactly fitted by a screw having the same axis, or having a tube twisted round it in the form of a screw If a small solid body were placed at the bottom, and the screw turned round, each point of the screw would pass beneath the body

at the lower edge of the cylinder, and the body would be gradually raised to the top In the same manner, if water has access to the bottom, on turning the instrument it will be raised until it flows out at the top Archimedean screws are extensively used for raising water in Egypt and in Holland

ARCHIMEDES, PRINCIPLE OF The law that, when a body is immersed in a liquid, it displaces a quantity of liquid equal in bulk to itself, and appears to be lighter in the liquid than in air, by the weight of the liquid displaced The principle receives its name from the following circumstance —It is said that Hiero, King of Syracuse, applied to Archimedes for a test to prove whether a crown which had been made by his orders was all gold, or whether the goldsmith had dishonestly substituted a baser metal for a portion of the gold While the philosopher was thinking of the subject, he chanced to enter a bath filled with water, and noticed that, as he entered, the liquid flowed over This observation suggested a solution to his problem He took the crown, and a quantity of pure gold of the same weight, and immersed them successively in the same vessel, filled to the brim with water As the crown displaced more water than the equal bulk of gold, he concluded that it was partly composed of a lighter metal, and the king's suspicions were confirmed

Assuming the alloy to be silver, Archimedes then took quantities of gold and silver equal in weight to the crown, immersed them in water, and weighed that which overflowed He was thus able to discover the extent to which the king had been defrauded in the construction of the crown (See *Specific Gravity* and *Displacement of Liquids*)

ARCTIC (ἀρκτικός, from ἄρκτος, a bear) The part of the heavens where the constellations of the Greater and Lesser Bear appear The North Pole of the heavens lies close by the latter constellation, and thus the term Arctic is now associated with the North Polar region of the heavens, rather than specially with the above-named constellations The arctic regions on the earth are those in which, at the time of the summer solstice, the sun does not set, the *arctic circle* marking the limit of those regions At places along this circle (neglecting refraction) the sun is on the horizon at midnight at the time of the summer solstice of the northern hemisphere.

ARCTURUS ('Αρκτοῦρος—from ''Αρκτος, a bear, and οὖρος, a warder, the Bear guard) The leading star of the constellation Bootes, and, according to Sir John Herschel's photometric experiments, the brightest star in the northern heavens

AREOMETER, MOHR'S Mohr's areometer consists of a glass tube containing mercury, and hermetically sealed at the top and bottom. It hangs from a fine platinum wire, and is sufficiently heavy to sink in every liquid which has to be examined The weight of the instrument in air being determined, it is suspended in water, and again weighed The loss experienced is the weight of an equal volume of water (See *Displacement of Liquids*) On weighing the instrument again in another liquid, and deducting the weight so found from the original weight, we find the weight of the same volume of the liquid Division of the weight of the volume of the liquid by the weight of the equal volume of water gives the specific gravity of the liquid When many determinations have to be made in a short time, it is, of course, sufficient to weigh the instrument only once in water, that is, to determine once for all the weight of water whose volume is equal to that of the instrument

AREOMETER, NICHOLSON'S An instrument for determining the specific gravities of solids and liquids It consists of a hollow cylindrical copper vessel, with conical ends The lower end is loaded, so as to secure an upright position when floating It also carries a little perforated tray at the lower end, the use of which will be described immediately The upper conical end carries a narrow stem which bears a small tray An arbitrary mark is made on the stem The solid, whose specific gravity has to be determined, is placed upon the upper tray, and weights are added until the mark on the stem sinks exactly to the level of the surface of the water in which the instrument is placed The substance is removed and replaced by weights until the areometer sinks to the same mark as before The weight which has to be added to effect this is the absolute weight of the substance This weight is again removed, and the object is put into the lower tray, that is, beneath the surface of the water The areometer will not sink to the mark, because the object in the tray is pushed up by a force equal to the weight of water it displaces To find this upward pressure, weights are placed on the upper tray until the instrument sinks to the same mark The weight required to effect this is the weight of a volume of water equal to the volume of the substance (See *Displacement of Liquids*) Accordingly, by dividing the weight of the body by the weight of an equal volume of water, the specific gravity is obtained

Nicholson's areometer may also be readily applied to the determination of the specific gravity of liquids Let the weight of the entire instrument be first ascertained Let it be placed in water, and, by the addition of weights on the upper tray, let it be sunk to the given mark. Let

it now be placed in another liquid, and weights added as before, until the same effect is produced The weight first added, together with the weight of the instrument, gives the weight of the volume of water equal to the immersed part of the instrument The second weight, added together with the weight of the instrument, gives the weight of the same volume of the liquid Hence the specific gravity is found by dividing the second sum by the first

ARGOL See *Tartaric Acid.*

ARGO NAVIS (Latin) In astronomy (*the ship Argo*), one of Ptolemy's southern constellations By modern astronomers it is divided into four portions, named respectively, *Malus*, the mast, *Vela*, the sails, *Carina*, the keel, and *Puppis*, the stern This constellation was figured in ancient maps as the aft section of a galley, the position of the ship being such that the diurnal motion of the heavens carries her sternwards Thus Aratus and Manilius compare the motion of the ship to that of a vessel dragged by the stern into harbour The constellation is remarkable for the singular richness with which stars are distributed over it It has been remarked by the late Captain Jacobs, the well-known observer, that one can tell when this constellation has risen above the horizon, without turning towards it, because the united lustre of the stars composing it sheds a light over the landscape resembling that of a young moon Within this constellation is the wonderful variable star Eta Argûs (see *Stars, Temporary*), situated in the heart of one of the most remarkable nebulæ in the heavens

ARIDED (Arabic) The leading star of the constellation Cygnus It is also called Deneb Adige

ARIES The ram, a constellation; but also the first sign of the Zodiac The commencement of this sign on the ecliptic is called *the first point of Aries*, it is the point in which the ecliptic passes from the southern to the northern side of the equinoctial line The sun's centre occupies this point at the vernal equinox of the northern hemisphere, and from this point longitudes are measured along the ecliptic, in the order of the signs, and right ascensions along the equator from west to east The *sign* Aries is at present occupied by the constellation Pisces

ARMATURE (*Armatura*, armour) To improve the power of the native loadstone as a magnet the position of the poles is determined, and while the distance between them is maintained as great as possible, the rough outlying portions of the stone are removed, so that it assumes something of a rectangular shape, two of the sides of the rectangle being perpendicular to the line joining the poles. To each of these ends is applied a smooth L-shaped piece of the softest iron, which terminates in a massive foot projecting below the side of the stone These soft iron pieces constitute the armature of the magnet They very much increase its power for lifting, concentrating it, as it were, in the soft iron feet, and besides enabling both poles to be applied at once, as is the case with the horse shoe magnet The word armature has, however, a somewhat doubtful application, a few writers denoting by it what is more frequently called a *keeper*

ARMILLARY SPHERE (*Armilla*, a bracelet) An instrument employed by ancient astronomers It consisted of a number of hoops representing the principal great circles on the celestial sphere, as the equator, ecliptic, &c, placed in their proper relative positions It may be questioned whether for teaching beginners a form of the armillary sphere might not still be employed with advantage It is worthy of notice that the instruction derived from treatises on astronomy is not usually effective in fixing in the student's mind a clear impression of what actually takes place in the heavens More particularly is this the case as respects the apparent motions of the sun, whether in his diurnal course round the heavens, or in his annual circuit of the ecliptic A certain reality (and as surely a new charm) would be given to the study of astronomy in our schools, if the solar apparent motions, the comprehension of which forms the basis of all astronomy, were directly measured and noted by the student By means of a rod placed like the gnomon of a sundial (that is, pointing to the pole of the heavens), and fixed circles corresponding to the meridian circle, the equator, the ecliptic, and so on, a variety of very simple and instructive lessons could be imparted The equable motion of the shadow of the rod on the equator would convince the student of the equable nature of the sun's apparent diurnal motion, and so of the equable nature of the earth's rotation to which that motion is due The varying midday elevation of the sun would in like manner be illustrated by the varying position of the shadow of the axial rod's centre at noon upon the meridian circle A number of such illustrations of the celestial motions could be readily devised, and there can be no question whatever that the student would gain a clearer and sounder understanding of the principles of astronomy (and that in a more agreeable manner), by such open air and practical illustrations than by mere reading

ARMSTRONG'S HYDRO-ELECTRIC MACHINE See *Electric Machine.*

ARNEB. (Arabic) The star α of the constellation Lepus.

AROMATIC GROUPS, HOMOLOGOUS. According to Dr. Odling.

	Primary Terms.		Secondary Term	
Phenyl Quinonic Family	C_6H_6	Phenene	C_6H_4	Phenylene
	C_6H_6O	Phenol		
	$C_6H_6O_2$	Pyrocatechin		
	$C_6H_6O_3$	Pyrogallin		
	$C_6H_4O_2$	Collic acid		
	$C_6H_6O_2$	Hydroquinone	$C_6H_4O_2$	Quinone
	$C_6H_6O_3$	Phloroglucin		
	$C_6H_4O_5$	Comenic acid		
Benzyl Salicic Family	C_7H_8	Benzone	C_7H_6	Benzylene
	C_7H_8O	Benzylic alcohol Cresylic phenol		
	$C_7H_8O_2$	Benzylic glycol		
	C_7H_6O	Benzoic aldehyd		
	$C_7H_6O_2$	Benzoic acid Saloic acid		
	$C_7H_6O_3$	Ampelic acid, &c		
	$C_7H_8O_2$	Saligenin Orcin	$C_7H_6O_3$	Oreoselin
	$C_7H_6O_2$	Salicic aldehyd		
	$C_7H_6O_3$	Salicic acid		
	$C_7H_6O_4$	Hypogallic acid, &c	$C_7H_4O_4$	Ellagic acid
	$C_7H_6O_5$	Gallic acid		
	$C_7H_6O_6$	Pergallic acid	$C_7H_4O_6$	Chelidonic acid
			$C_7H_4O_7$	Meconic acid

ARRAGONITE See *Calcium*

ARSENIC A metallic element known (in its compounds) from a very early date, but investigated chemically by Brandt in 1733 Its symbol is As, and atomic weight 75, it is occasionally found native, but more frequently in combination with iron, copper, cobalt, and nickel ores In the metallic state it is of a steel gray colour, specific gravity from 5 62 to 5 96 It is very brittle, and crystallises in rhombohedrons When heated it volatilises without fusion at a dull red heat, and condenses either in a compact metallic mass, or a dark gray powder, according to conditions The principal compounds of arsenic are the following —Oxides of arsenic, of which there are two, the *trioxide or arsenious acid* and the *pentoxide or arsenic acid*

Arsenious acid (As_2O_3), commonly called arsenic, or white arsenic, is a white, solid, crystalline, or amorphous substance The amorphous variety is a transparent, vitreous substance, produced when its vapour condenses on a hot surface, the crystalline variety is formed when the vapour is condensed more quickly, or when it separates from its solutions, the specific gravity of the former is 3 7385, and that of the latter 2 695 Arsenious acid volatilises at 218° C (424° F), its vapour is colourless and very dense (specific gravity, 13 85) Arsenious acid is readily reduced to the metallic state when heated with a reducing agent By allowing its vapour to pass over a splinter of red hot charcoal in a small glass tube, a ring of metallic arsenic is condensed on the cool portion of the tube, by the further application of heat this may be driven up and down the tube, and gradually reoxidised into arsenious acid, which, under the microscope, appears in brilliant octahedrons, these reactions are characteristic of the metal When bright metallic copper is boiled in a solution containing arsenic, the metal is reduced on the surface of the copper, forming a steel gray layer When the piece of copper is dried and heated in a clean glass tube the above reaction can be performed It dissolves in about 30 parts of cold water, and in 10 or 12 parts of hot water Its solution is acid to test paper, acids dissolve it more readily, it unites with bases forming arsenites The only arsenites of importance are *arsenite of copper* ($Cu_4As_2O_5$), known as *Scheele's Green*, the *aceto-arsenite of copper* (3 Cu As O_2 $C_2H_3Cu\,O_2$) *Arsenite of iron* when excess of hydrated sesquioxide of iron is mixed with solution of arsenious acid, the whole of the latter unites with the iron, to form a basic arsenite Owing to this property, hydrated sesquioxide of iron is one of the best antidotes to arsenious acid, it should be administered in great excess, and freshly precipitated *Arsenite of silver*, a yellow precipitate, is formed when an alkaline arsenite is added to a solution of nitrate silver, its formula is 2 $Ag_2O.As_2O_3$

Arsenic Acid (As_2O_5), formed by oxidising arsenic or arsenious acid to the fullest extent It forms several hydrates, which are readily soluble in water It is a strong acid, forming arseniates with bases, the only one of importance is the silver salt (Ag_3AsO_4), a dark brown precipitate obtained when an alkaline arseniate is added to nitrate of silver Arsenic acid readily parts with its extra quantity of oxygen with reduction to arsenious acid, hence it is sometimes used as an oxidising agent in manufacturing operations

Arseniuretted Hydrogen (AsH_3) A colourless gas very slightly soluble in water, and extremely poisonous, it is formed when hydrogen is generated in a solution containing arsenic, or by dissolving zinc containing arsenic, in acid When this gas is heated in a tube to dull redness it is decomposed, and metallic arsenic condenses, when passed through a solution of nitrate of silver, silver only is precipitated, and the whole of the arsenic goes into solution as arsenious acid The gas is inflammable, and evolves a white smoke of arsenious acid, by depressing a cold porcelain surface into the flame, metallic arsenic precipitates as a lustrous mirror For the distinction between arseniuretted hydrogen and antimoniuretted hydrogen the reader is referred to works on analytical chemistry

Chloride of Arsenic —A colourless, oily, dense liquid, of the composition $AsCl_3$, formed with ignition when powdered arsenic meets with chlorine

Sulphides of Arsenic —Of these there are three AsS, As_2S_3, and As_2S_5 The first, the di sulphide, was known to Pliny and Vitruvius under the name of Sandarica It is now known as realgar, red orpiment, or ruby sulphur It is a transparent, ruby coloured crystalline mass, easily fusible It was formerly used as a pigment, but is now frequently replaced by less dangerous bodies The tri-sulphide of arsenic, the arsenicum of Pliny, now known as orpiment or yellow sulphide of arsenic, is a fine lemon-coloured powder, formerly used as a pigment, and sometimes employed in calico printing

Pentasulphide of Arsenic is not known in the separate state, but only in combination with sulphides of other metals

All the sulphides of arsenic act the part of sulpho acids, and unite with metallic sulphides to form sulpho salts

Arsenic forms many organic compounds, of these we can only mention one, and its compounds, viz, Cacodyl, formerly known as *Cadet's Fuming Liquid*, or *Alkarsin* It is now supposed to be a compound of two equivalents of methyl and one of arsenic ($As(CH_3)_2$), and in modern nomenclature is called arsendimethyl Its preparation must be effected with extraordinary precautions owing to its spontaneous inflammability and its extremely poisonous nature Bunsen's research on cacodyl is a masterpiece of chemical accuracy Cacodyl is a transparent colourless liquid, heavier than water, it has a disgusting odour, and its vapour is extremely poisonous, it boils at 170° C (338° F), and solidifies at 6° C (43° F) to a crystalline mass, it is slightly soluble in water more so in alcohol it takes fire in the air at ordinary temperatures, and also in chlorine gas It acts the part of a radical, and forms an oxide, chloride, iodide, and other compounds which need not be further specified

ARSENICAL GREEN See *Acetates*

ARSENIURETTED HYDROGEN See *Arsenic*

ARTESIAN WELL This well has its name from the Province of Artois, in France Its principle, however, in no wise differs from that of ordinary springs or wells When liquids are in communicating vessels, the surfaces of the two portions are in a horizontal plane (See *Liquids, Level Surface of*) If the edge of one of the vessels be not so high as that of the other, and the second be kept full, the first must continually overflow The strata of the earth's upper crust have various powers of absorbing water In many districts the surface layer is clay, which is penetrated with difficulty by water Beneath this there may be gravel and chalk, which both absorb and yield great quantities of water with facility If the three strata are bent into a cup shape so that the edges of the gravel or chalk are exposed the rain falling on these will soak in and accumulate beneath the impervious clay, while the rain which falls upon the latter will be freely removed by the water courses Accordingly, a locality with a clay soil may be suffering from drought, while there is abundant water beneath it pressing upward with a force proportional to the difference of level between the clay and the edge of the exposed lower strata where they crop up On piercing the clay into the chalk the water will rise in the boring, and will gush forth with a velocity dependent upon the above difference of level

ARTIFICIAL TOURMALINE See *Iodoquinine*

ASBESTOS (ἀσβεστος, indestructible) A mineral containing silicate of magnesia, occurring in minute fibres and filaments There are many varieties, the one most known is called amianthus (Greek, ἀμιαντος, undefiled, α, not, and μιαινω, to pollute), from its resistance to fire, this occurs in long silky fibres, very flexible and elastic, and of a white colour, they are separated from each other, and have been woven into fireproof cloth, which, when soiled, [illegible] by heating in the fire.

ASCENDING NODE See *Node*.

ASCENSION, RIGHT (*Ascensio*, advance) The right ascension of a celestial body is the angle between two planes, one passing through the pole of the heavens and the body, and the other through the pole of the heavens and the first point of Aries (See *Aries*) Since right ascensions are measured on the equator from west to east, while the diurnal rotation of the heavens takes place from east to west, it is clear that a star, having a given right ascension, will come to the meridian later than the first point of Aries, by an interval equal to that in which the earth rotates through an angle equal to the star's right ascension Thus if a star's right ascension is 15 degrees, the star will come to the meridian one hour after the first point of Aries, since the earth rotates through 15 degrees in one hour Right ascension is, therefore, commonly measured in hours, minutes, and seconds of time, instead of in degrees, minutes, and seconds of arc (See *Declination*, and *Equatorial*) In old works on astronomy the term oblique ascension is sometimes met with The oblique ascension of an object is the arc between the first point of Aries and that point on the equator which comes to the horizon at the same time as the object It obviously varies with the latitude of the place of observation

ASCENSIONAL DIFFERENCE The difference between the oblique and the right ascension of a celestial object (See *Ascension, Right*) The term is now obsolete

ASH OF PLANTS See *Plants, Ash of*

ASPECT A term used by astrologers See *Astrology*

ASSAYING (*Essayer*, to try) An analytical operation in which, as a rule, one ingredient of a compound is alone determined Moreover, it applies to metallic alloys only, and is usually restricted to those of silver and gold Hence, assaying is one of the cardinal operations in all Mints Sir John Pettus, in his *Dictionary of Metallick Words* (1683), says, "I take Assaying to have relation only to things of weight, as metals, &c, from the word *As*, or *Assis* (which signifies a pound weight, or 12 ounces, or the whole of any substance which may be divided into parts), and especially applicable to the greatest or smallest coins that are made of any metal, which many times were, and still are, of copper or brass, which the Latins call *Æs*, and, therefore, I suppose, it is sometimes writ *Essaying*" (See also *Cupellation*)

ASTATIC (*α*, without, and *στάω*, to stand) An arrangement of magnetic needles such that the earth shall have no directive action upon them, is called an *astatic combination*, and sometimes simply an *astatic needle* It is usual to suspend two equal needles parallel to one another and horizontal, so that the plane which contains them shall be vertical, and their like poles are turned in opposite directions Such a system is made use of in experiments on the directive force of currents of electricity upon magnets, used in galvanometers It is possible also to make a single needle astatic by placing magnets near to it, or by suspending it upon an axis in the magnetic meridian, and parallel to the line of magnetic inclination

ASTATIC GALVANOMETER, or, *Multiplier* (See *Multiplier*, *Thermomultiplier*)

ASTERISM (*ἀστηρ*, a star) Properly, any collection or group of stars, but now commonly limited to small groups, as distinguished from constellations

ASTEROIDS (*ἀστεροειδής*, resembling a star) The name given to members of the zone of small planets travelling between the orbits of Mars and Jupiter Although correctly designating the aspect of these bodies, which are not readily distinguishable from the fixed stars, save by the experienced observer, the name can hardly be considered as well chosen, since in all their real attributes these bodies are altogether different from the fixed stars

The discovery of the first known members of this zone forms one of the most interesting chapters in the history of astronomy It had long been noticed that a large gap separates the orbit of Mars from that of Jupiter Not, indeed, that the actual distance between these orbits is even so great as that which separates the orbits of Jupiter and Saturn But the orderly increase observable in the planetary distances as we proceed outwards from the sun, is obviously marred by the sudden increase which marks the interval between the orbits of Jupiter and Mars as compared with that between the orbits of Mars and the earth This circumstance led Kepler, and afterwards Titius, to express the opinion that an undetected planet revolves between Mars and Jupiter The discovery of the planet Uranus, whose mean distance corresponds exactly with Bode's law, led Bode to assert his belief that astronomers might with advantage search for such a planet Accordingly, for the first time in the history of astronomy, an empirical law, a law whose cause is even now not recognised, led astronomers to commence a systematic survey of the heavens Through the exertions of Baron de Zach, an association of twenty-four astronomers was formed These observers divided the zodiac between them, and shortly after the commencement of the present century, the search for the new planet was fairly commenced But the discovery did not fall to the lot of any of those who had undertaken the search As in the case of the planet Uranus, an apparent accident brought the first discovered member of the family of asteroids under the notice of an astronomer who richly merited such

a success, though actually engaged on work of another character Piazzi, the eminent Italian astronomer, at work on his great catalogue, was carefully surveying the constellation Taurus, when his attention was attracted by an apparent change of place in a small star, which he had observed on the first day of the present century By January 3, 1801, he had convinced himself of the star's change of place He communicated his discovery to Oriani and Bode, and continued his own observations until February 11, when his labours were interrupted by dangerous illness. When his letters reached Oriani and Bode, the planet had already approached too near to conjunction with the sun to be discernible There seemed great risk that after all the planet would escape astronomers, since it would not be discernible before September 1801, and the observations of Piazzi were deemed insufficient for the calculation of the planet's place after so long an interval But Gauss, the eminent mathematician, came to the rescue, and after a careful study of all the observations made by Piazzi, he formed an ephemeris of the planet's path for several months in advance At length, after an arduous search, De Zach redetected the planet on December 31, 1801, Olbers (independently) discovering it on the following evening After one year of doubt and difficulty, astronomers had succeeded in securing a well earned triumph for their science It was found that the new planet travels at a mean distance of 2 767 from the sun, the earth's distance being unity, while Bode's law had indicated for it a distance of 2 8 It therefore fulfilled even more closely than was to have been expected this empirical law It was called Ceres by Piazzi.

But while astronomers were congratulating themselves on this new proof of the existence of law and harmony within the solar system, a fresh discovery threatened to throw all into disorder again While searching for Ceres, Olbers had noticed with special care the arrangement of the small stars which lay near its assigned geometric path On March 28, 1802, while examining a part of the constellation Virgo, he noticed a small star in a part of the heavens which had thus been rendered familiar to him, the star occupying a place where he felt sure no star had been visible while his search for Ceres had been in progress In two hours he had recognised the planetary motion of this body By April 28, Gauss had assigned to the newly discovered planet, which received the name Pallas, an orbit having a mean distance very little less than that of the planet Ceres Thus there were now two planets where only one had been wanted to supply the gap in the planetary scheme Olbers was led to expect that others would be found, and a search being instituted for the purpose of testing this view, Harding of the Lilienthal Observatory discovered, on September 2, 1804, the planet Juno Next, on March 20, 1807, exactly five years after his discovery of Pallas, and in the same region of the heavens, Olbers discovered Vesta

Thirty-eight years now passed before any further addition was made to the family of asteroids, Astræa, discovered on December 8, 1845, being the fifth in order of recognition But from the discovery of Hebe, on July 1, 1847, not a year has passed without adding one or more asteroids to the list of known planets In some years the progress of discovery has gone on more rapidly than in others Thus, in 1861 *ten* asteroids were discovered, in 1868 *twelve*, while in each of the years 1863 and 1869 only *two* were discovered But at present there seems to be no reason to expect that a year will ever pass without adding to the list The following table presents all the asteroids discovered up to the date of writing, with the name of the discoverer and the place and date of discovery —

No	Name	Date of Discovery	Discoverer	Place of Discovery
1	Ceres	1801, January 1	Piazzi	Palermo
2	Pallas	1802, March 28	Olbers	Bremen
3	Juno	1804, September 1	Harding	Lilienthal
4	Vesta	1807, March 29	Olbers	Bremen
5	Astræa	1845, December 8	Hencke	Driessen
6	Hebe	1847, July 1	Hencke	Driessen
7	Iris	August 13	Hind	London
8	Flora	October 18	Hind	London
9	Metis	1848, April 25	Graham	Markree
10	Hygeia	1849, April 12	De Gasparis	Naples
11	Parthenope	1850, May 11	De Gasparis	Naples
12	Victoria	September 13	Hind	London
13	Egeria	November 2	De Gasparis	Naples
14	Irene	1851, May 19	Hind	London
15	Eunomia	July 29	De Gasparis	Naples
16	Psyche	1852, March 17	De Gasparis	Naples
17	Thetis	April 17	Luther	Bilk
18	Melpomene	June 24	Hind	London
19	Fortuna	August 22	Hind	London

No	Name	Date of Discovery	Discoverer	Place of Discovery
20	Massilia	1852, September 19	De Gasparis	Naples
21	Lutetia	November 15	Goldschmidt	Paris
22	Calliope	November 16	Hind	London
23	Thalia	December 15	Hind	London
24	Themis	1853, April 6	De Gasparis	Naples
25	Phocea	April 6	Chacornac	Marseilles
26	Proserpina	May 5	Luther	Bilk
27	Euterpe	November 8	Hind	London
28	Bellona	1854, March 1	Luther	Bilk
29	Amphitrite	March 1	Marth	London
30	Urania	July 22	Hind	London
31	Euphrosyne	September 1	Ferguson	Washington
32	Pomona	October 26	Goldschmidt	Paris
33	Polyhymnia	October 28	Chacornac	Paris
34	Circe	1855, April 6	Chacornac	Paris
35	Leucothea	April 19	Luther	Bilk
36	Atalanta	October 5	Goldschmidt	Paris
37	Fides	October 5	Luther	Bilk
38	Leda	1856, January 12	Chacornac	Paris
39	Lætitia	February 8	Chacornac	Paris
40	Harmonia	March 31	Goldschmidt	Paris
41	Daphne	May 22	Goldschmidt	Paris
42	Isis	May 23	Pogson	Oxford
43	Ariadne	1857, April 15	Pogson	Oxford
44	Nysa	May 27	Goldschmidt	Paris
45	Eugenia	June 28	Goldschmidt	Paris
46	Hestia	August 16	Pogson	Oxford
47	Aglaia	September 15	Luther	Bilk
48	Doris	September 19	Goldschmidt	Paris
49	Pales	September 19	Goldschmidt	Paris
50	Virginia	October 4	Ferguson	Washington
51	Nemausa	1858, January 22	Laurent	Nismes
52	Europa	February 6	Goldschmidt	Paris
53	Calypso	April 4	Luther	Bilk
54	Alexandra	September 10	Goldschmidt	Paris
55	Pandora	September 10	Searle	Albany, U S
56	Melete	1857, September 9	Goldschmidt	Paris
57	Mnemosyne	1859, September 22	Luther	Bilk
58	Concordia	1860, March 24	Luther	Bilk
59	Olympia	September 12	Chacornac	Paris
60	Echo	September 15	Ferguson	Washington
61	Danaë	September 19	Goldschmidt	Chatillon-sous Bagneux
62	Erato	October 10	Forster	Berlin
63	Ausonia	1861, February 10	De Gasparis	Naples
64	Angelina	March 4	Tempel	Marseilles
65	Cybele	March 8	Tempel	Marseilles
66	Maia	April 9	Tuttle	Cambridge, U S
67	Asia	April 17	Pogson	Madras
68	Leto	April 29	Luther	Bilk
69	Hesperia	April 29	Schiaparelli	Milan
70	Panopea	May 5	Goldschmidt	Fontenay aux Roses
71	Niobe	August 13	Luther	Bilk
72	Feronia	May 29	Peters	Clinton, U S
73	Clytie	1862, April 7	Tuttle	Cambridge, U S
74	Galatea	August 29	Tempel	Marseilles
75	Eurydice	September 22	Peters	Clinton, U S
76	Freia	October 21	d Arrest	Copenhagen
77	Frigga	November 12	Peters	Clinton, U S
78	Diana	1863, March 15	Luther	Bilk
79	Eurynome	September 14	Watson	Ann Arbor, U S
80	Sappho	1864, May 3	Pogson	Madras
81	Terpsichore	September 30	Tempel	Marseilles
82	Alcmene	November 27	Luther	Bilk
83	Beatrix	1865, April 26	De Gasparis	Naples
84	Clio	August 25	Luther	Bilk
85	Io	September 19	Peters	Clinton, U S.
86	Semele	1866, January 6	Tietjen	Berlin
87	Sylvia	May 16	Pogson	Madras
88	Thisbe	June 15	Peters	Clinton, U S.
89	Julia	August 6	Stephan	Marseilles
90	Antiope	October 1	Luther	Bilk
91	Ægina	November 4	Stéphan	Marseilles
92	Undina	1867, July 7	Peters	Clinton, U S
93	Minerva	August 24	Watson	Ann Arbor, U S.

No	Name	Date of Discovery	Discovery	Place of Discovery
94	Aurora	1867, September 26	Watson	Ann Arbor, U S
95	Arethusa	November 23	Luther	Bilk
96	Ægle	1868, February 17	Coggia	Marseilles
97	Clotho	February 17	Tempel	Marseilles
98	Ianthe	April 18	Peters	Clinton, U S
99	Dike	May 29	Borelly	Marseilles
100	Hecate	July 11	Watson	Ann Arbor, U S
101	Helena	August 16	Watson	Ann Arbor, U S
102	Miriam	August 22	Peters	Clinton, U S
103	Hera	September 7	Watson	Ann Arbor, U S
104	Clymene	September 13	Watson	Ann Arbor, U S
105	Artemis	September 16	Watson	Ann Arbor, U S
106	Dione	October 10	Watson	Ann Arbor, U S
107	Camilla	November 17	Pogson	Madras
108	Hecuba	1869, April 2	Luther	Bilk
109	Felicitas	October 9	Peters	Clinton, U S.
110	Lydia	1870, April 19	Borelly	Marseilles

The most remarkable characteristics of the asteroids are their smallness, and the relatively wide range of eccentricity and inclination among their orbits Their distances vary between about 200 and more than 300 millions of miles The eccentricity of Polyhymnia is no less than 339119, so that its greatest distance is more than twice its least The inclination of Pallas is 34° 43′, so that the excursions of this planet above and below the ecliptic exceed, when taken together, the mean distance of the planet from the sun

Leverrier has shown, by means of calculations founded on the secular motion of the perihelion of Mars, that the combined mass of all the asteroids, (discovered and undiscovered), cannot greatly, if at all, exceed one-fourth of the mass of our earth, and probably bears a much smaller ratio to the earth's mass

Professor Kirkwood of America has shown that when the distances of the asteroids are arranged in order, certain well marked gaps make their appearance In other words, *there are no asteroids having mean distances lying near certain definite values* These values correspond to distances at which asteroids would revolve in periods associated with the period of Jupiter according to certain simple laws of commensurability Professor Kirkwood deduces conclusions favourable to the general principle on which the nebular hypothesis is founded He further compares the peculiarity in question with the existence of a great gap in the Saturnian ring system, showing that a satellite revolving within that gap would have a period associated with the periods of the inner satellites of Saturn according to simple laws of commensurability

ASTROLABE (ἀστρόλαβος) An instrument used by ancient astronomers for observing the stars Its principle resembled that on which many modern instruments are founded,—as the equatorial, the alt-azimuth, and the theodolite It consisted mainly of graduated circles, having a common centre Sights carried round these circles, or in some instances the motion of the circles themselves, served to indicate the angular distances of the celestial bodies from each other, or from fixed celestial points or circles, as the case might be The instrument was used for a variety of purposes, but gradually fell into disuse after Ptolemy's invention of the stereographic projection

ASTROLOGY (ἄστρον, a star, λεγω, to order, arrange) This term should, properly speaking, be used to indicate what we now understand by the word astronomy It has for a long time been limited, however, to the pretended art of divining future events from the motions of the stars In this sense it is commonly spoken of as "judicial astrology," because its professors pretended to form a judgment respecting future events

So long as men supposed the earth to be the centre of the universe, and the sun, moon, stars, and planets to be all intended for her benefit, there was something not altogether unreasonable in the belief that each of the celestial bodies exerts its own peculiar influences If the sun pours more light and heat on the earth at certain times than at others, it was conceivable that the special action which each planet and star was intended to exert would also vary It only remained to determine (or failing the possibility of this, to *guess*) what was the nature of the influence exerted by each celestial body, and under what circumstances such influence was most powerfully called into action, in order to be able to form an opinion as to the condition of the objects affected by the celestial influences And since it was possible to determine beforehand where the celestial bodies would be given at any time, it would follow that men could anticipate the future fate of all creatures thus affected, as certainly as they could predict the season of harvest or of vintage Assume only that mankind is included among the creatures whose lot is influenced by the motions of the celestial bodies, then precisely as one can predict that a seed sown

out of due season will not germinate, so one can predict that a man born when the planets were exerting unfavourable influences will be unsuccessful in life

When we consider that in the infancy of astronomy there appeared just this germ of reason in the views of astrologers, it is hardly to be wondered at that astrology should in old times have taken a firm hold of men's minds, or that even now it should be found by charlatans an ever ready means of deceiving the ignorant Considering how ready men have been to draw conclusions respecting the future from circumstances which seem to have absolutely no bearing whatever on future events, as from the condition of the entrails of animals, from lines on the hand, and even from the combinations of playing cards—it is not surprising that the influences which the planets and stars might reasonably enough be supposed to exert, should be eagerly studied, and the lesson of futurity seem clearly legible in the calculated motions of these orbs

It would certainly not be fitting that men of the present age should sneer overmuch at the credulity of those who in olden times believed unquestioningly in the decrees of judicial astrology It would be well if all the superstitions which live in our day had even that small basis of probability on which the ancients rested their belief in stellar influences

It is against the founders of the doctrine of astrology, rather than against those who put faith in them, that our diatribes should be directed It is impossible to conceive that *they*, at any rate, had any belief in what they taught They must have formed the laws of their pretended science entirely at random, being at pains, indeed, to give reasons for their selection of such and such influences, as associable with such and such celestial bodies, but, undoubtedly, conscious that the selection had been made at random It is only necessary to mention a few of their pretended laws of divination to see that this is so Saturn and Mars were supposed to exert evil influences, while Venus and Jupiter were benignant, and Mercury and the sun indifferent Dividing the heavens into 12 houses by certain circles, they called the first house the "house of life," the second, "the house of riches," the rest, in order, referring to "brothers, parents, children, health, marriage, death, religion, dignities, friends, and enemies" The planetary aspects were characterised in a similarly arbitrary manner, opposition and quadrature being malignant, trine and sextile benignant, and conjunction indifferent

But, perhaps, the most remarkable part of the history of astrology is that which belongs to the period immediately following the invention of the telescope The professors of astrology set themselves busily to work to find suitable influences for the spots on the sun, the satellites of Jupiter, and so on Nay, we find, that even observers of repute were willing to devote a large part of the treatises, in which they described their discoveries, to the attempt to explain the influence of newly-discovered objects on the lives and fortunes of men

It is fortunate for the charlatans who, in our day, profess to believe in astrology, that they have not felt bound, like their predecessors, to assign suitable influences to all the celestial objects, since, otherwise, the zone of asteroids and the periodic comets would have painfully taxed their inventive powers

ASTROMETER (*ἄστρον*, a star, and *μέτρον*, a measure) An instrument, devised by Sir John Herschel, for estimating the brightness of the fixed stars The essential object of the instrument is to bring an image of Jupiter, the moon, or some other object of recognised brightness, into direct comparison with a star, so that star and image are seen in the same direction By adjusting the distance of the image, so that it appears equal in brightness to the star, and measuring this distance, the lustre of the star is readily determined

Bouguer applied the term astrometer to the heliometer

ASTRONOMICAL EYE-PIECE See *Negative Eye-piece*

ASTRONOMY (*ἄστρον*, a star, *νέμω*, to classify) The science which deals with the distribution, motions, and characteristics of the heavenly bodies

There can be little doubt that astronomy is the most ancient, as in certain respects it is the most noble, of the sciences From the earliest ages, thoughtful men have contemplated, with interest and wonder, the phenomena presented by the celestial bodies, so that it is not without reason that Gassendus has ascribed the birth of astronomy to admiration And gradually, as one phenomenon after another was detected, it began to be recognised that, independently of its singular charm, the study of the heavens may be made to subserve, in an important manner, the interests of the human race. By supplying convenient modes of measuring time, and marking the progress of the seasons, by affording the traveller a means of guiding his course over pathless wastes, or the wide expanse of ocean, and, later, by supplying exact means of measuring and surveying the earth, the "stars in their courses" minister importantly to the wants of men It has been in relation to these, and other useful purposes, that *practical* astronomy has been specially cultivated During the progress of observations made in pursuance of such objects, there have arisen numberless questions of interest associated with the laws of the celestial motions, and the physical attributes of the celestial bodies. In the examination of

these questions *physical* astronomy has taken its rise These important divisions of the science have progressed for many ages on parallel courses, though not always *pari passu*

There are few questions which have given rise to more discussion, and have led to less satisfactory conclusions, than the problem of determining to which nation of antiquity the origin of astronomy is to be attributed The Chaldæans have been considered by many as the first who studied the science, and we have undoubted evidence that at a very early epoch observations of considerable accuracy were made at Babylon Calisthenes transmitted to Aristotle observations made there about 2250 years before Christ The invention of the Saros (see *Cycle*) indicates also an accuracy of observation, and an attentive scrutiny of results, which force us to form a high opinion of the Chaldæan astronomers Some even have supposed that they had determined the true nature of the planetary motions, but the evidence on this point is too vague and unsatisfactory to be accepted Chinese astronomy has high claims to antiquity, but the accuracy of the older Chinese observations is more than questionable The phenomena recorded in the works of Confucius are merely announced as facts, not with astronomical accuracy M Bailly has discovered that a conjunction of Mars, Jupiter, Saturn, and Mercury, adopted as an epoch by the Emperor Chwen-hio, occurred on February 28, B C 2449, between α Arietis, and the Pleiades In the reign of the Emperor Chou kang, the chief astronomers *Ho* and *Hi* (probably these were the names of their offices) were condemned to death for having neglected to announce a solar eclipse, which took place B C 2169 It has recently been shown by Mr Williams, Assistant Secretary of the Astronomical Society, that the chief characteristics of modern Chinese astronomy, and especially the instruments now in use, were introduced by the Jesuit missionaries Still there can be no doubt that in very ancient times, long before the age of Meton in fact, the Chinese were in possession of the Metonic and Calippic cycles The claims of the Hindus to be the inventors of astronomy have given rise to much dispute Bailly regarded the Hindu astronomy as exceedingly ancient, but as founded on a yet more ancient astronomy, the invention of the Atlantides An argument of considerable weight against the invention of their own system by Hindu astronomers, is founded on the circumstance, that in their sacred books astronomical phenomena and relations are described which belong to a latitude much farther north than that of Benares But, weighty as this argument is, M Bailly laid too much stress upon it when, without direct evidence of any sort, he invented a nation, assigned that nation a local habitation and a name, and attributed to them learning so high, as to justify the remark of d'Alembert, that they would seem to have taught mankind everything except that the Atlantides ever existed

Recently, Professor Piazzi Smyth, Astronomer Royal for Scotland, has pointed to many striking evidences in favour of the view that the architects of the Great Pyramid were acquainted with many astronomical facts usually regarded as modern discoveries, and as he places the construction of this pyramid in a far antiquity, it would follow, if we accept his inferences, that the nation which built the pyramid were the real inventors of astronomy He points out reasons for believing that the astronomical epoch, to which the Great Pyramid corresponds, is the last occasion when the star α Draconis, was 3° 42′ from the pole of the heavens, or 2170 B C At this period the Pleiades were almost exactly opposite, and α Draconis in Right Ascension, but they were ' in a most peculiar cosmical position, well worthy of being monumentally commemorated, for they were actually at the commencing point of all right ascension, or at the very beginning of running that grand round of stellar chronological mensuration which takes 25,868 years to return into itself again, and has been termed elsewhere, for reasons derived from far other studies than anything hitherto connected with the Great Pyramid, the *great year of the Pleiades*" It must be remarked, however, that, striking and most interesting as are many of the relations pointed out by Professor Smyth, one must not accept without extreme caution results founded on mere numerical coincidences There have been instances in which the most striking coincidences have been proved to be mere accidents One even of those insisted upon by Professor Smyth must be regarded as accidental He shows that the sum of the diagonals of the pyramid's base amounts to 25,836 inches, corresponding closely to the number of years in the great precessional cycle, according to the best and latest researches But elsewhere he remarks that a side of the pyramid's base contains as many sacred cubits (each 25 British inches) as there are days in the year—*i e*, 365 25 One of these relations must of necessity be accidental, since the length of the side determines the length of the diagonal, while there is no connection at all between the number of days in the year and the number of years in the great precessional cycle

The astronomy of the Greeks seems to have been derived from the Egyptians The founder of the Ionian or earliest school of Greek astronomy was Thales of Miletus (A D 600) He exhibited the nature of the lunar and solar motions, explained the inequality of the days and nights in different seasons, and determined the length of the solar year To him also has been

attributed the selection of the Lesser Bear in place of the Greater, as a polar constellation A century later Pythagoras made important advances in astronomy He exhibited the spherical shape of the earth, and is held by some, though on insufficient grounds, to have taught that the sun is the centre of the planetary motions What he really taught, according to the statement of Philolaus, was, that "the earth and planets move in oblique circles (or ellipses) about fire, as the sun and moon do" It may be that the last words were added by Philolaus, in which case we may believe that Pythagoras had discovered the true system But the evidence is too vague for any confident belief on this point To the Ionian school belongs the honour of having invented the Metonic Cycle, though some doubt exists whether Meton detected the period which bears his name

Eudoxus of Cnidus, (who died about B C 368), determined the length of the lunar month, and adopted the year of 365¼ days He was among the earliest to deal with the difficulties which the looped paths of the planets oppose to the theory that the earth is the centre of the planetary motions

Passing over the work of Timocharis, Aristyllus, and Apollonius of Perga, we come to the most eminent of all the astronomers of old, the famous Hipparchus of Nicæa He was essentially a student of practical astronomy He estimated the length of the tropical year within 4½ minutes of its true value, determined the mean motion of the sun, detected the eccentricity of the solar orbit, and assigned the places of its apogee and perigee He examined the lunar motions with equal care, determining the motion of the moon's nodes and of her apogee, the eccentricity of her orbit, the equation of her centre, and her mean inclination He constructed tables, invented processes resembling those of plane and spherical trigonometry, and devised the application of parallax to determine the distances of celestial objects He also formed a catalogue of 1081 stars, which has been justly termed "one of the most valuable bequests of antiquity" The greatest of his works, however, was his discovery of the *precession of the equinoxes* (See *Precession*)

Ptolemy is chiefly famous as the inventor of the system which bears his name, (*Ptolemaic System*,) though the work he did as an observer has been altogether more valuable to the science of astronomy He discovered the lunar evection

Between the age of Ptolemy and the foundation of modern astronomy we find the students of the science chiefly occupied in endeavouring to reconcile the celestial motions with the principles of the Ptolemaic System Good work was indeed done by Arabian and Persian astronomers during that long interval, but the belief in an erroneous theory vitiated the whole series of labours carried on by astronomers

With the researches of Nicholaus Copernik, (who died in 1543) modern astronomy may be said to have taken its rise Though unable to get rid entirely of the complexities and difficulties which surrounded the Ptolemaic system, yet by placing the sun in the centre of the planetary scheme and by showing the earth to be but a member of the sun's family, he exhibited a simplicity and harmony in the solar system which it had hitherto wanted (See *Copernican System*)

Tycho Brahe endeavoured to replace the earth at the centre of the universe, (see *Tychonic System*,) but the observations which he carried out with the special intention of overthrowing the Copernican System, became in the hands of Kepler the means of establishing that system on a firmer foundation (See *Keplerian System*)

The publication of Kepler's two first laws (in 1609), and the almost simultaneous announcement by Galileo of the discovery of Jupiter's satellites, the phases of Venus, and a number of other phenomena having an obvious relation to the new views respecting the universe, led all the more advanced astronomers to accept with confidence the Copernican System But it was not till Newton had established the theory of gravitation (*q v*), that the true system can be said to have been placed beyond a doubt So long as the motions of the planets were regarded with simple reference to kinematical principles, there was, in fact, no real means of demonstrating that Tycho Brahe's system was not the true explanation of the celestial motions It was only when men began to recognise the dynamical principles involved in the planetary motions that it became impossible for them to accept the earth as the centre of those movements

Bradley's discovery of the *aberration of the celestial bodies*, (*q v*), supplied a new and perfect demonstration of the Copernican theory But the events which have characterised the progress of astronomy since the time of Newton form parts of a system too wide to be dealt with in this section The reader is therefore referred to separate headings for an account of the discoveries made in the various departments of modern astronomy It is unnecessary to point out what those headings are, but it may be remarked that under such general headings as The *Solar System*, *Planets*, *Nebula*, *Stars*, *Comets*, and so on, the reader will find mentioned the

headings of the subordinate subjects whose study may be necessary to complete his general survey of the science

Among the immense number of treatises which have been written on astronomy, we may select for special mention, Delambre's *Histoire d'Astronomie*, and his *Traité d'Astronomie, Théoretique et Pratique*, Sir John Herschel's *Outlines of Astronomy*, and Professor Grant's *History of Physical Astronomy*

ASTRO-PHOTOMETER An instrument described by Zollner for measuring the intensity of the light of celestial bodies Its description is too complicated to be understood without woodcuts, but it is described in Zollner's "Grundzuge einer allgemeinen Photometrie des Himmels, Berlin, 1861" The following intensities were obtained by Zollner by comparing the sun or planets with α Aurigæ, he found that the intensity of the sun was 55,760,000,000 times that of Capella, with a probable error of about 5 per cent Hence for the intensity of the mean opposition—

			Prob error
Sun =	6,994,000,000 times	Mars,	5 8 per cent.
Sun =	5,472,000,000 ,,	Jupiter,	5 7 ,,
Sun =	130,980,000,000 ,,	Saturn (without the ring),	5 0 ,,
Sun =	8,486,000,000,000 ,,	Uranus,	6 0 ,,
Sun =	79,620,000,000,000 ,,	Neptune,.	5 5 ,,
Sun =	619,600 ,,	Full Moon,	2 7 ,,
And by comparing surfaces, Sun = 618,000 times Full Moon,			1 6 ,,

From the above it follows that our sun, at a distance of 3 72 years-way of light, would appear like Capella with a parallex of 0 874 seconds Zollner found the reflecting power to be as follows —

Moon,	0 1736	Saturn,	0 4981
Mars,	0 2672	Uranus,	0 6400
Jupiter,	0 6238	Neptune,	0 4648

For the sake of comparison, we give the following determinations of the reflecting power of terrestrial substances

By diffused reflected light—		Regular reflection—	
Snow just fallen,	0 783	Mercury,	0 648
White paper,	0 700	Speculum metal,	0 535
White sandstone,	0 237	Glass,	0 040
Clay marl,	0 156	Obsidian,	0 032
Quartz porphyry,	0 108	Water,	0 021
Moist soil,	0 079		
Dark gray syenite,	0 078		

ATACAMITE See *Copper*

ATHERMANCY (α, not, θέρμη, heat) A term introduced by Melloni to designate the property of stopping the passage of radiant heat It is thus the opposite of diathermancy, and corresponds to opacity in the case of light, in fact, an athermanous substance is sometimes spoken of as being *opaque to heat* (See also *Diathermancy*)

ATLANTIC TELEGRAPH Information as full as our limits permit on the subject of telegraphy in general, and submarine telegraphy in particular, will be found under the heads *Telegraph* and *Cable, Submarine* Here we propose to give a few details on the subject of the construction and working of the Atlantic cables

The credit of originating the idea, or at least of maturing it, is due to Mr Cyrus W Field, but probably no undertaking of the kind ever before engrossed the attention and called to its aid the powers of so many scientific men, mathematicians, electricians, and engineers, and none ever aided pure science so much by assisting discovery and stimulating research Peculiar difficulties which had not been encountered, or had only been encountered to a very small extent in the previous short lines, were met with, both in engineering and in electric testing and signalling, and the talent of England and America were called into play to overcome them. We regret that our space does not permit us to tell the exciting story of the many trials and failures of the steady perseverance and indomitable energy and courage of the promoters and undertakers of the scheme, of the triumph over difficulties and successful laying of the 1866 cable, and of the still greater feat, the recovery and completion of the lost 1865 cable, for these we refer our readers to *The Atlantic Telegraph*, by Dr W H Russell

In 1857, the first attempt to lay an Atlantic cable was made Starting from Valentia, 330 knots were submerged when the cable broke, owing to defective paying-out machinery. In

the summer of 1858, the same cable was taken on board by the "Niagara" and "Agamemnon," a splice was made in the middle of the Atlantic, and the vessels commenced paying out. Thrice the cable broke, but at the fourth trial the operation was successful, and a cable connected Ireland with Newfoundland. Unfortunately there was a slight fault in the cable, which rapidly became worse and worse, till after a few days communication altogether ceased, not, however, before several messages had been transmitted and the feasibility of an Atlantic Telegraph had been demonstrated. Between 1857 and 1858, Sir William Thomson had showed the great difference in the conductivity of various specimens of copper wire, and had proved that proper selection of copper wire may increase the speed of telegraphing by at least 30 per cent. The mirror and marine galvanometers had also been invented, and were used in signalling through the cable in 1858, and in testing on board the vessel.

The 1858 cable consisted of seven copper wires twisted into one strand, a number of wires being used instead of a single thick one, in order that if one should break from twisting or bending the cable, or in any other way, the continuity of the conductor may not be destroyed. Over these gutta percha was laid in three coatings, and the whole protected by eighteen strands of iron wire, each strand being composed of seven wires, which were laid spirally round the core, being separated from it by a padding of hemp saturated with tarry mixture. The weight was 20 cwt per knot in air, and 13.4 cwt in water, and its breaking strain was 3 tons 5 cwts, so that the cable would bear a little less than five miles of itself suspended in water. The distance from Ireland to Newfoundland is 1670 miles, and 2174 miles of the cable were shipped for the purpose of laying.

After the loss of this cable great difficulty was experienced in obtaining the requisite funds to carry on the construction and laying of another, and though those who were most competent to judge were the most sanguine about the ultimate success of the undertaking, it was not till 1865 that a new cable was made and sent to sea. In the meantime great advance had been made in the knowledge of the true principles of submarine telegraphy, and the mechanical arrangements for submerging a cable had been very much improved. The "Great Eastern" took the cable on board, and commenced the laying from Valentia on the 23d of July 1865. All went well, though many difficulties were encountered, till the 2d of August, when, as the cable was being hauled back, in order to remove a faulty portion paid out, it chaffed against the bows of the "Great Eastern," parted, and went overboard in 2000 fathoms of water, the length of cable paid out being 1186 miles, and the distance from Heart's Content, Newfoundland, 606.6 miles.

After several attempts to recover the cable by drifting over the spot with grapnels trailing, during which they hooked it and almost dragged it on board, they were forced through defective picking-up machinery to abandon the enterprise for the time, but with the satisfaction of having proved the probability of success. Next year another cable was ready, and the "Great Eastern" again started from Valentia, and laid it almost without a hitch. Then came again the grand engineering experiment of picking up the lost one, and on the 2d of September 1866, Sir Samuel Canning telegraphed to Sir Richard Glass that he had much pleasure in speaking to him through the 1865 cable. The cable was completed on the 8th of September.

The form of these cables is much the same. The copper conductor consists of seven wires (gauge No. 18), weighing 800 lbs. per nautical mile. These are made into a single strand, and are embedded in a pitchy mixture called Chatterton's compound. Over this are laid four layers of gutta percha alternately with three of Chatterton's compound, the diameter of the core thus formed being 0.464 inches. The object of using so many coatings is, that if an air bubble should occur in any one of them, the great pressure to which the cable is exposed may not be able to force water completely through to the conducting wire, and thus to effect the destruction of the insulation. The external protection consists of 10 solid wires (No. 13 gauge), surrounded separately by Manilla yarn, which has been saturated with a preservative compound, and these are laid spirally round the core previously padded with hemp. The weight in air is 35 cwt. 3 qrs., and in water 14 cwt. per knot, and the breaking strain is 7 tons 15 cwt.—that is, the cable would bear 11 nautical miles of itself suspended in water. The deepest water was 2400 fathoms. The length of the 1865 cable is 1896 knots, and of the 1866 cable 1858 knots, the total resistance of the 1865 cable is 7604 B.A. units, that of the 1866 cable 7209 B.A. units, and the resistance of the gutta percha insulator per knot is 2437 millions of B.A. units after one minute electrification, and it rises to 7000 millions of B.A. units after being electrified for 30 minutes.

The battery used for sending is that which we have described under the name of Menotti's battery, though, we believe, it has been invented by a number of electricians, and is called by many names. Twenty cells are used, though not more than twelve are necessary. The receiving instrument is Thomson's Galvanometer. (See *Reflecting Galvanometer.*) The alphabet is made

by the vibrations of the spot of light to the one side or to the other Under *Electricity, Velocity of*, we have spoken fully of the nature of the charging and discharging of such a cable as the Atlantic, and it will be readily understood from what we have said there that reading by an instrument, such as any of those in use in ordinary telegraphy, would be very slow indeed We should have to wait for each signal until the cable was completely or nearly completely charged, but by the delicate reflecting galvanometer the very commencement of the electric flow may be observed

In order to obviate as far as possible the effects of induction, an arrangement due to Mr Varley is made use of At Valentia the cable is connected with one coating of a condenser of very great capacity, the galvanometer being placed between the condenser and the cable When signals are to be sent from Newfoundland, the other coating of the condenser is kept connected with the earth At each depression of the sending key a flow of electricity takes place into the condenser, or out of it, as the case may be, and the flow backwards and forwards taking place through the galvanometer gives rise to motion of the spot of light, thus producing signals Again, when Valentia telegraphs to America, the condenser is electrified positively or negatively by induction, and gives rise to a corresponding flow backwards or forwards through the cable By this arrangement the prolongation of the signal (See *Electricity, Velocity of*) is avoided, and as there is no proper voltaic circuit, the disturbance due to *earth currents*, which would be much felt by such a sensitive receiving instrument, is also prevented

The signals are, as we have said, produced by the movements from one side to the other of the spot of light reflected from the moving mirror of the galvanometer The rate of transmission is very great indeed It is said that, when the clerks speak with each other, as high a speed as eighteen words per minute is obtained About half this rate is adopted in transmitting public messages

The reader who desires further information will find it in *The Atlantic Telegraph* before referred to, in two articles in *Good Words*, 1867, the *North British Review*, 1866, and in the *Athenæum*, August to November, 1856, also in the papers of Sir William Thomson and others communicated to the British Association for the Advancement of Science and to the Royal Society

ATMOMETER (ἀτμός, vapour, and μέτρον, measure) An instrument for measuring the evaporation from a moist surface There are several contrivances for this purpose One of the simplest consists of a long graduated tube of glass, with a hollow ball of porous earthenware attached to its foot The tube is filled with water, which soaks the substance of the hollow ball The water sinks in the tube as the process of evaporation goes on at the surface of this ball, the rate at which the water sinks indicating the rate of evaporation

ATMOSPHERE (ἀτμός, vapour, and σφαῖρα a sphere) The envelope of gases and vapours which surrounds the earth It consists of two distinct portions, the permanent atmosphere, whose amount does not depend on ordinary variations of temperature, and the vaporous portion, whose amount is far less considerable than that of the permanent atmosphere, and is variable with changes of temperature, &c

Pressure of the Atmosphere—The fact that the atmosphere has weight, and so exerts pressure, was suspected by Aristotle, and asserted by Epicurus But the former failed to convince himself by experiment that air has weight, and accordingly until the middle of the seventeenth century, it was commonly accepted that the air is weightless The experiments of Torricelli and Otto de Guericke proved, however, that the air not only has weight, but at the earth's surface exerts enormous pressure Torricelli's main experiment was that which forms the fundamental principle of the *Barometer* (q v) It shows that the pressure of the air at the earth's surface is capable of supporting a column of mercury about 30 inches in height, in other words, that the weight of the whole atmosphere is equal to that of an ocean of mercury covering the whole earth, and about 30 inches deep It follows from this that on every square inch of surface, near the sea level, in whatever position such surface may be inclined, there is exerted a pressure of about 14 6 lbs The pressure on a square foot is very nearly a ton, and it has been calculated that the actual pressure exerted by the air on the surface of a human body of average stature is equivalent to a weight of somewhat more than 14 tons It is only because this pressure is balanced by the pressure of elastic fluids within the body that it produces no sensible inconvenience

For the atmospheric pressure on different parts of the earth's surface see *Isobarometric Lines*

At any given place the pressure of the atmosphere varies sensibly from day to day, and even from hour to hour Under the heads, *Barometer*, *Weather*, &c, some of these changes will be considered There are systematic changes whose full consideration would require more space than is here at our disposal It may be mentioned, however, that as regards the annual variations of barometric pressure, in temperate latitudes, a double period may be recognised.

The two maxima occur in winter and summer, the winter maximum exceeding the summer one The minima occur near the equinoxes, and are appreciably equal The diurnal variation also exhibits a double period There is a morning minimum at about a quarter before four, followed by a maximum in somewhat less than six hours (more exactly, at 9h 37m A M), then the pressure decreases till about 4h 5m P M , after which it rises till about 10h 11m P M , which is the hour of the evening maximum These hours vary somewhat, however, for different stations In tropical countries the diurnal oscillations of the atmospheric pressure are much more marked, and exhibit much more regularity than in our latitudes

Height of the Atmosphere—Very little is known with certainty respecting the actual limits of the atmosphere From the duration of twilight it has been calculated that the atmosphere has a height of about 45 miles , but there can be little doubt that this estimate falls very far short of the truth Other calculations founded on the duration of twilight at elevated stations give very different results Thus Bravais, from a discussion of Lambert's observations, deduced a height of nearly 100 miles His own observations made from the summit of the Faulhorn gave a height of about 66 miles Dr Balfour Stewart considers that the best means of judging would be by observations made on the aurora From such observations made in 1819, Dalton estimated the extreme height of the auroral light at 102 miles Sir John Herschel estimated the height of an auroral arch seen on March 9, 1861, at 83 miles From observations made on meteors, it has been concluded that the atmosphere is at least 100 miles high , and some observations of this sort have even been made which suggest the belief that the air may reach to a height of more than 200 miles M Liais was led by observations made in 1859, on the polarisation of the sky, to the conclusion that the atmosphere extends to a height of no less than 212 miles

Density of the Atmosphere—The law according to which the atmosphere diminishes in density with distance from the earth s surface depends on principles which, theoretically considered, are sufficiently simple , but as actually observed, the variations of density, though according generally with the deductions from theory, are yet marked by peculiarities of a somewhat complex nature, resulting from the duplex character of the atmospheric constitution As affording an approximately correct view of the subject, the following easily remembered law may be given "*At a height of seven miles the density of the atmosphere is reduced to one fourth the density at the sea level, and for every increase of height by seven miles, the rarity of the air is similarly quadrupled*" So that since pressure is proportional to density, at a height of seven miles, the air would support a column of mercury about $7\frac{1}{2}$ inches only in height , at a height of 14 miles the supported column of mercury would be less than 2 inches high , at a height of 21 miles it would be less than half an inch high, and so on It is obvious from these considerations that there must be a definite limit to the extension of the atmosphere, since the elasticity of the air must at a certain height, be so reduced as to be just balanced by the attraction of gravity on the atmospheric molecules

ATMOSPHERE, COMPOSITION OF THE The term *Atmosphere* is applied to an envelope of gaseous matter surrounding any substance Thus we speak of distilling liquids in an atmosphere of carbonic acid, and of reducing oxides by heating in an atmosphere of hydrogen The term is, however, generally used in reference to the earth's atmosphere The true composition of the atmosphere was not known till the year 1774, when Lavoisier pointed out that it consisted of two gases, one of which was a supporter of life and combustion, and the other the reverse The former he found to be identical with Priestley's "vital air," now known as oxygen, and the latter he called azote or nitrogen, and showed that the atmosphere contained about one fifth of its volume of oxygen and four fifths of nitrogen The other normal constituents of the atmosphere are aqueous vapour, ozone, carbonic acid, and ammonia, besides accidental constituents such as nitric acid, sulphurous acid, carbonic oxide, hydro carbons, products of organic decomposition, and the minute solid particles constituting dust, and rendered visible when a beam of electric light or ray of sunshine traverses a dark room The accurate analysis of air has occupied the attention of chemists for many years, and the result of their labours has been to show that the percentage by bulk of oxygen in the atmosphere, whether taken from the top of a mountain, from a balloon, over the sea, in a London court, or in the country, varies very slightly between 20 65 and 20 99 of oxygen The carbonic acid varies much more considerably, the average being about four volumes in 10,000, rising perhaps to ten times that amount in crowded rooms, theatres, &c , and sinking sometimes to about three volumes The aqueous vapour depends so largely on temperature and rainfall that its variations can be reduced to no rule, the limits being none at all, and absolute saturation, and the variations at the same place frequently approaching one or the other within a few days The ammonia exists in very small quantity, and the analysis by different observers vary greatly, the maximum being 135 parts, and the minimum one part in a million Although in such minute quantity, it appears to play an important part in vegetation, and hence in animal

nutrition, for most, if not all, the nitrogen of the plant is derived from atmospheric ammonia Ozone is generally present in the atmosphere, except in crowded cities and under abnormal conditions, but no trustworthy method of estimating its amount being known, no analytical results can be given The normal composition of the atmosphere is altered by respiration, putrefaction, and combustion, which remove oxygen from it and add carbonic acid, and it is altered in the opposite direction by vegetation, by which carbonic acid is absorbed and oxygen is evolved, a balance in this manner is in some degree kept up, and the atmosphere is rendered fitted for the requirements of living beings Further information on the composition of the atmosphere may be obtained by reference to Dr Angus Smith's papers read before the Chemical Society and the Literary and Philosophical Society of Manchester, and published in their Transactions (See especially Journal Chem Soc xi 196)

ATMOSPHERE, ELECTRICAL It was supposed by some that round an electrified body there exists a certain space within which it can act to decompose, as they expressed it, the neutral electricity of unelectrified bodies The sphere of this action is termed the *electrical atmosphere* of the body As far as we know, however, there is no limit by distance to the action of induction, and hence the term electrical atmosphere is worse than useless

ATMOSPHERES OF THE PLANETS We have evidence, derived not only from telescopic observation but from the surer teachings of the spectroscope, that the planets have atmospheric envelopes, though as yet we have no means of assuring ourselves of the actual constitution of the atmosphere of any planet Accepting the nebular hypothesis, whether as originally presented by Laplace or in a modified form, we should have further evidence deduced from the consideration of the results which might be expected to follow from the processes according to which the various planets are supposed to have been formed, according to that theory Many interesting questions are suggested by the various relations which we may suppose the planetary atmospheres to bear to the orbs they surround It has been conceived that by such varieties the different distances of the planets from the sun, and the consequent differences in the amount of heat they receive from him, may be more or less completely compensated Mr Hopkins of Cambridge has shown that the planet Mars, with an atmosphere about 15,000 feet higher than the earth's, would have a climate similar to hers, and that the planet Venus, if her atmosphere corresponded to that portion of the earth's atmosphere which lies above the height of 25,000 feet, measured from the sea-level, would have a maximum temperature not exceeding that at the earth's equator We owe to Dr Tyndall the explanation of the circumstance on which such considerations are founded He has shown that it is not the air itself which prevents the earth's heat from being radiated into space, but the aqueous vapour present in the air Other vapours have an even greater power of preventing the radiation of heat from a low temperature source, like the heated surface of the earth and Dr Tyndall remarks that an atmosphere might be formed which would act the part of a *barb* to the solar rays, "permitting their entrance towards a planet, but preventing their withdrawal," and that thus a comfortable temperature might be obtained on the surface of the most distant planets It seems open to question, however, whether the actual circumstances of our own atmospheric surrounding can be approximated to on any other planet, still less on those planets which are very near to, or very far from the sun, by any such arrangement, since the great excess or defect of direct solar heat must always remain uncompensated

ATMOSPHERE, OPALESCENCE OF THE See *Opalescence of the Atmosphere*

ATMOSPHERE, REFRACTIVE POWER OF See *Refractive Power of the Atmosphere*

ATMOSPHERIC ELECTRICITY Some of the most striking natural phenomena, such as lightning, thunder, and also some more quiet, but not less remarkable luminous appearances are due to the existence and the discharge of electric accumulations in the atmosphere Franklin was the first observer in this field The resemblance of lightning to the electric spark had been spoken of before, but till the time of his request to the European investigators to make the trial, nothing was done to prove the identity of the two At Franklin's suggestion, M D'Alibard in France erected a pointed rod in 1752, and by means of it obtained electricity from a thunder cloud But before any account of his experiments had reached Franklin, he himself, tired of waiting for the erection of a spire in Philadelphia for the experiment, bethought him of flying a kite during a thunder storm, and thereby communicating with the upper regions and with the clouds The kite was flown by a common hempen string, to the end of which was attached a key, and the key, by means of a silk cord, to a tree He presented his hand to the key, but at first obtained no result He was about to give it up in despair, when some rain having fallen and wetted the string, it became a conductor, and he perceived a slight spark Afterwards more rain fell, and he obtained a copious flow of sparks He describes his joy at the discovery as being such that he could not refrain from tears

Soon there was a host of investigators in the field, as Nollet and Beccaria, Richman, who was

killed by lightning while experimenting, Volta, and others, and since that time we have had many observers But though much has been done, and many facts have been collected, the subject cannot yet be said to be well understood, and careful observations in all places and positions are much required Hitherto the want of an accurate and manageable electrometer has been a hindrance, but within the last few years the invention and perfecting of the electrometer of Sir William Thomson has done away with the difficulty, and even already results have been obtained and are accumulating We deal in this article not with the effects of electric force, such as lightning and thunder, which are discussed under their proper heads, but rather with its existence in the atmosphere and the laws of its distribution as far as we know them

The principles on which our deductions on the subject are founded are laid down in a remarkable paper by Sir W Thomson, published in Nichol's Encyclopædia, and in a lecture delivered at the Royal Institution, May 18, 1860, both republished with his other electrical papers We shall begin by briefly restating these principles, for the fullest information, the papers themselves must be consulted

In order to know thoroughly the distribution of electricity throughout an insulating body, it is necessary to know, for every point in it, the resultant force in magnitude and direction Of this kind of information, we have none whatever at the present time, and to gain it, observations with the aid of the balloon would be necessary We know, however, something of the distribution of electricity over the earth's surface and from this knowledge we are able to make certain important deductions with regard to the electrification of the upper strata of the atmosphere

The whole of the earth's surface is at all times electrified, with the exception of neutral lines which divide positively electrified portions from portions which are negative On the whole, the extent of the negatively electrified part is much greater than that of the positive part, in fact, it is only in bad weather, or under the influence of some disturbing cause, that positive electrification of the surface exists at all If the earth were simply an electrified body, undisturbed by the influence of any electrified matter external to it, or of any conductor in its neighbourhood, the electricity would be distributed over the surface according to a definite law, depending only on the form of the surface If we knew this distribution, any discoverable variation from it must be due to an external cause, and though we do not know it, yet from observing the changes which occur in it from time to time, we equally infer an external cause, and to some extent we are able to deduce the nature of that cause

In the first place, we find that these changes are connected in many cases with powerful atmospheric disturbances, as in the case of the presence of thunder clouds We also find that even the smaller changes depend upon the state of the weather Thus, as was mentioned above, in broken weather we observe positive electrification of the earth's surface, which never occurs in fair and serene weather To some extent, also, it has been shown that certain winds are connected with certain changes in the electric distribution Thus Sir W Thomson was able almost to predict the occurrence of east wind by finding a particularly high electrical induction The changes, too, are frequently so very rapid that they can hardly be conceived to be due to anything but the influence of electrified bodies of air moving at a not very great distance from the earth's surface

In order to show the existence of electric force in the atmosphere, it is only necessary to attach to the upper plate of an electroscope a metallic rod carrying at the top a piece of touch paper On lighting the touch paper the gold leaves will very soon show signs of electric excitement The quality of the electricity may be determined in the usual way by approaching an excited rod of glass or sealing wax The effect of the burning touch paper is to throw off continually particles of matter charged oppositely to the air at the point of the conductor Soon, therefore, the conductor is reduced to the same state as the air, and therefore the gold leaves also which are connected with it As has been mentioned, in fine weather the earth's surface is always negatively electrified The air, therefore, and the electroscope will be found in this case to be positively charged For full particulars as to the modes of collecting, measuring, and recording observations on atmospheric electricity, the reader must consult the articles upon *Observatories*, *Meteorological*, and upon *Electrometers*

During serene and cloudless weather the electricity of the atmosphere is always positive, and of an amount depending to a certain extent upon the position of the place at which the observation is taken, and varying from time to time at the same place At high and isolated places the amount is greatest, in enclosed places, such as between walls, in streets, and so on, but little is to be found It increases as we rise through the atmosphere During dry weather it is generally greatest, and it appears especially during the occurrence of east winds, at least in some places At sunrise the amount is small, it appears to increase up till between the hours of eleven and eight, the time of the maximum depending upon the season From this time it

decreases, till it attains a minimum a little before sunset, and a few hours after sunset it takes a second maximum, from which time it decreases till sunrise again It seems also that the winter average is higher than that of the summer months In stormy and wet weather the electricity observed is frequently negative, it is very variable, however, and as yet no law has been given on the subject Generally, too, the clouds are electrified, sometimes positively and sometimes negatively It will be seen from the meagre account we have been able to give with respect to actually observed facts, that we are yet in want of much observation, both regular and taken simultaneously at different stations Within the last few years several self registering electrometers have been set up both in England and abroad, and even already some results have been published

Several theories of the causes of atmospheric electricity have been put forward, but as yet none very satisfactory The cause cannot be said to be known It has been ascribed to evaporation, which it has been shown produces electric excitement under certain circumstances, and the earth has by some been compared to a voltaic pile in which the electricity is excited by chemical action, and sometimes to a thermo electric arrangement The friction of the air has also been supposed to be the exciting cause Experiments in proof of any of these theories are wanting

ATMOSPHERIC ENGINE See *Steam-engine*

ATMOSPHERIC LINES OF THE SPECTRUM Sir David Brewster has shown that some of the black lines observed in the solar spectrum are due to absorption of certain rays by the atmosphere The French physicist, Janssen, has proved that, when light is passed through a considerable thickness of steam at high pressure, it produces strongly marked absorption bands, which coincide with Brewster's groups of lines, and which become more intense when the sun is on the horizon, and the atmosphere charged with aqueous vapour M Janssen has named these lines the telluric lines of the solar spectrum (See *Absorption of light, Spectrum*)

ATMOSPHERIC PRESSURE See *Atmosphere*

ATOM (Ατομος, from α, not, and τεμνειν, to be cut) The finite or the infinite divisibility of matter, and the consequent existence or non-existence of atoms which do not admit of further division, have furnished food for speculation among many of the leading minds in various ages and countries But the ingenious ideas of Greek and Indian philosophers, of Latin poets and Epicureans, have had little or no influence on modern science Bacon refers to them as "such glimpses of truth as can be obtained by the intellect left to its own natural impulses, and not ascending by successive and connected steps," as taught by the inductive philosophy The ancient notion was, that the ultimate elements of matter consist of minute, simple, indivisible, indestructible particles, which idea, being adopted and extended by Newton, has had great influence on the progress of science not only among chemists, but also among physicists, in founding important theories of chemical, thermal, and electrical phenomena and also as respects crystallographical form Newton's expressions are very remarkable He says, "All these things being considered, it seems probable to me that God, in the beginning, formed matter in solid, massy, hard, impenetrable, moveable particles of such sizes and figures, and with such other properties, and in such proportions to space, as most conduced to the end for which He formed them, and that the primitive particles being solids, are incomparably harder than any porous bodies compounded of them, even so very hard as never to wear or break in pieces, no ordinary power being able to divide what God had made one in the first creation While the particles continue entire, they may compose bodies of one and the same nature and texture in all ages, but should they wear away or break in pieces, the nature of things depending on them would be changed Water and earth, composed of old worn particles and fragments of particles, would not be of the same nature and texture now with water and earth composed of entire particles in the beginning And, therefore, that nature may be lasting, the changes of corporeal things are to be placed only in the various separations and new associations and motions of these permanent particles, compounded bodies being apt to break, not in the midst of solid particles, but where these particles are laid together, and only touch in a few points"

It is astonishing how largely the above views have furnished suggestions to various subsequent theories The authority of Newton has always been so great, that even his speculations have been received as truths It is related that, on one occasion, Sir Isaac and Dr Bentley met accidentally in London, and on Sir Isaac's inquiring what philosophical pursuits were being carried on at Cambridge, the doctor replied, "None, for when you go a hunting, Sir Isaac, you kill all the game, you have left us nothing to pursue" Much of our science since Newton's time has been cultivated in the spirit of this reply Results must on no account contradict Newton's philosophy If true to nature, so much the better, they must be true to Newton This worship has been reproved by one who cannot possibly be accused of want of reverence to Newton. The late Master of Trinity, referring to Newton's hypothesis of ulti-

mate particles, makes the following remarks:—"When we would assert this theory, not as a convenient hypothesis for the expression or calculation of the laws of nature, but as a philosophical truth respecting the constitution of the universe, we find ourselves checked by difficulties of reasoning which we cannot overcome, as well as by conflicting phenomena which we cannot reconcile."

The historian of the Inductive Sciences, just quoted, gives the arguments for and against atoms, and we must refer to his works any reader desirous of going further into these curious speculations. We do not attempt even to indicate them here, since they belong rather to metaphysics than to physics. Such reasoning as this was felt to be untenable, that the properties of bodies depend on the attractions and repulsions of the particles, and their hardness on such forces; for if the hardness depend, say upon the repulsion of the particles, on what does the hardness of the particles depend? The hardness and solidity of the particles were given up, and the theory of Boscovich adopted, according to which matter consists not of solid particles, but of mere mathematical centres, from which proceed forces according to certain mathematical laws, by virtue of which such forces become at certain small distances attractive, at certain other distances repulsive, and at greater distances attractive again. "From these forces of the points arise the cohesion of the parts of the same body, the resistance which it exerts against the pressure of another body, and, finally, the attraction of gravitation which it exerts upon bodies at a distance."

But the idea that the properties of bodies depend on forces emanating from immoveable points of their mass, did not escape the sagacity of Newton. He says: "Many things induce me to believe that the rest of the phenomena of nature, as well as those of astronomy, may depend upon certain forces by which the particles of bodies, in virtue of causes not yet known, are urged towards each other, and cohere in regular figures, or are mutually repelled and recede; and philosophers, knowing nothing of these forces, have hitherto failed in their examinations of nature."

This line of speculation has been followed up with assiduity by Laplace and others with great benefit to the progress of science; but, as Whewell remarks, "The assumption in the reasoning of certain centres of force acting at a distance, is to be considered as nothing more than a method of reducing to calculation that view of the constitution of bodies which supposes that they exert force at every point. It is a mathematical artifice of the same kind as the hypothetical division of a body into infinitesimal parts, in order to find its centre of gravity; and no more implies a physical reality than that hypothesis does."

There is a lesson based on the idea of matter consisting of solid, hard, indestructible particles, which we also owe to Newton—namely, the doctrine of the permanency of nature and the assurance that her laws do not alter with the course of time; for if such particles could break or wear, "the structure of material bodies now would be different from that which it was when the particles were new." It is further to be remarked, that this lesson which teaches the uniformity of the laws of nature is the major premiss in the logic of induction.

Attempts have been made, but in vain, to find a limit to the divisibility of matter. Dr Thomson has shown that a portion of lead which cannot exceed the 888,492,000,000,000th of a cubic inch is still visible; and Mr Tomlinson has given a calculation, based upon the quantity of soap contained in a soap bubble, known to be of less thickness than a 2,600,000th of an inch. "Pure water will not hold together in this way, but the admixture of less than the hundredth of its bulk of soap will confer this property on the whole of the water. Now, in order to produce this effect, it is evident there must be a portion of soap (at least *one* atom) in every cubic 2,600,000th of an inch of the solution. Therefore, a single atom of soap in the solid state cannot possibly occupy so much as the hundredth of a cubic 2,600,000th of an inch—that is, not so much as a 1,757 trillionth (1,757,000,000,000,000,000,000th) of a cubic inch."

The view taken of the term atom in modern chemistry will be found under *Atomic Theory*, *Atomicity*, &c.

ATOMIC HEAT. Equal weights of different bodies require different amounts of heat to raise them through the same number of degrees of temperature. See *Specific Heat*. Thus to raise a pound of iron from 32° to 33° requires 0.11379 of a unit of heat, while only 0.0324 of a unit is required to raise the temperature of a pound of platinum by the same amount. But Dulong and Petit in 1819 made the remarkable observation with regard to elementary substances, that, if instead of using equal weights of the bodies, quantities in proportion to their atomic weights are employed, and the amounts of heat required to raise these quantities through one degree of temperature are determined, they will be found to be either identical or to bear a very simple numerical relation to each other. Thus 56 and 197 are respectively the atomic weights of iron and platinum; the amount of heat required to raise 56 pounds of iron through 1° Fah. is 56×0.1138 or 6.3728, while that required to raise 197 pounds

of platinum through 1° is 197 × 0.0324 or 6.3828. Regnault calls the number got by multiplying together those which express the atomic weight and specific heat of a body its *Atomic Heat*. This number represents, of course, the quantity of heat required to raise the so-called atom through one degree of temperature. The following table shows the specific heat, the atomic weight, and the atomic heat of a number of the elements:—

Elements	Specific Heat	Atomic Weight	Atomic Heat
Sulphur,	0.1776	32	5.6832
Selenium,	0.0837	79.5	6.6541
Tellurium,	0.0474	129	6.1146
Magnesium,	0.2490	24	5.9076
Zinc,	0.0955	65	6.2075
Cadmium,	0.0567	112	6.3504
Aluminium,	0.2143	27.5	5.8932
Iron,	0.1138	56	6.3728
Nickel,	0.1091	58.5	6.3823
Cobalt,	0.1070	58.5	6.2595
Manganese,	0.114	55	6.2700
Tin,	0.0562	118	6.6316
Tungsten,	0.0334	184	6.1456
Copper,	0.0951	63.5	6.0389
Lead,	0.0314	207	6.4998
Mercury (solid),	0.0319	200	6.3800
Platinum,	0.0324	197	6.3828
Palladium,	0.0593	106.5	6.3154
Rhodium,	0.0580	104	6.0320
Osmium,	0.0306	199	6.0894
Iridium,	0.0326	197	6.4202
Iodine,	0.0541	127	6.8707
Bromine (solid),	0.0843	80	6.7440
Potassium,	0.1696	39	6.6144
Sodium,	0.2934	23	6.7482
Lithium,	0.9408	7	6.5856
Arsenic,	0.0814	75	6.1050
Antimony,	0.0508	120.3	6.1076
Bismuth,	0.0308	210	6.4680
Thallium,	0.0336	203	6.8208
Silver,	0.0570	108	6.1560
Gold,	0.0324	196	6.3504

From this table it appears that the law of Dulong and Petit holds approximately. The divergence from it is accounted for by the fact that during the determination of the specific heat all the elements were not in the same physical state as to aggregation, distance from the melting point, and so forth; as it is well known that a difference in state makes a very great difference in the specific heat of the body.

This law with regard to the atomic heat of bodies is of great importance, as it gives us the means of aiding our judgment in determining their atomic weights from the results of analysis. Thus it has frequently happened that uncertainty exists as to whether a certain number or its double is the atomic weight of a given body, and the decision between the two is made by multiplying the number by the specific heat of the body and comparing the result with the numbers which express the atomic heats of other similar bodies.

Neumann and Regnault determined the atomic heat of many compound bodies and came to the conclusion that *bodies of similar chemical composition have similar atomic heats*; the atomic heat of one class of compounds may, however, differ from that of another class. For instance, Regnault showed by eight examples that the atomic heats of the bichlorides (such as chloride of barium, $Ba\,Cl_2$, chloride of zinc, $Zn\,Cl_2$,) are all very approximately 18.65; and by four examples, that in the carbonates, such as carbonate of calcium, $Ca\,C\,O_3$, carbonate of barium, $Ba\,C\,O_3$, it varies but little from the number 21.60.

ATOMICITY. An *atom*, in modern chemistry, is regarded as the smallest portion of matter that can exist in combination such as H = 1, while a *molecule* is the smallest quantity of matter that can subsist by itself, and this is supposed to contain two atoms, as H H = 2.* In this way the free molecules of the elementary gases are analogous in structure to hydro-chloric acid, in which a single atom of hydrogen is united to a single atom of chlorine, forming two volumes of hydro-chloric acid gas. In like manner, water in the form of vapour, (or *water gas*, as Hofmann terms it), consists of two atoms of hydrogen united to one of oxygen, the three

* In the cases of phosphorus and arsenium the ultimate molecule contains four atoms, and in those of cadmium and mercury the molecule contains a single atom only.

volumes being condensed into two So also in the case of ammoniacal gas, three atoms of hydrogen are in union with one of nitrogen, the four volumes being condensed into two, and lastly, in marsh gas four atoms of hydrogen are in union with one of carbon, the five atoms being condensed into two

The atomic symbols as well as the molecular are referred to the standard atom $H = 1$ But there is a distinction between the *molecule forming* equivalent of the elements, or the proportions by weight in which they can replace each other, and the *atom fixing* equivalents, or the proportions in which the elementary atoms replace each other in fixing a standard atom The carbon molecule, for example, = 12, but its atom fixing weight = 3, since in the marsh gas molecule, 12 parts of C fix 4 atoms of H, so that each atom of H is fixed by $\frac{12}{4} = 3$ parts by weight of C So also in ammonia N fixes 3 H and $\frac{14}{3} = 4\ 66$ is the atom fixing minimum of N Again, in water H_2O $\frac{16}{2} = 8$, the atom fixing minimum of O, but Cl in HCl fixes only 1 atom of H, and the atomic weight of Cl 35 5 does not in such case admit of subdivision

In this way we may assign to each element two numbers, (1) its minimum weight with respect to the formation of a molecule, (2) its minimum weight with respect to the fixing of an atom But to avoid the complexity likely to arise from the use of this double system, it is customary in elementary books to attach to each symbol a number in Roman letters, or simply one or more dashes to indicate how many standard atoms the weight referred to is capable of satisfying Thus we write Cl^{I}, O^{II}, N^{III}, C^{IV}, or Cl', O'', N''', C'''' This atom fixing power is termed *atomicity*, and the elements are arranged in groups of *monads*, *dyads*, &c Professor Hofmann uses the word *quantivalence* to express atomicity and *univalent*, *bivalent*, *trivalent* and *quadrivalent* to express *monatomic*, *diatomic*, *triatomic*, and *tetratomic*

ATOMIC THEORY This term is applied to three grand laws which form the foundation of chemical science, and are known as (1) the law of *definite* proportions, (2) the law of *multiple* proportions, and (3) the law of *atomic* or *equivalent* proportions If not discovered, they were first brought into the light of intellectual day by Dalton By the law of definite proportions the nature and proportions of the constituent elements in every chemical compound are definite and invariable For example, a piece of chalk, or Iceland spar, or any other of the numerous varieties of carbonate of lime, however much they may differ in form and other physical properties, have the same chemical composition wherever met with That is, every carbonate of lime (or calcic carbonate, as it is now called) contains in 100 parts 56 of lime (or oxide of calcium CaO) and 44 of carbonic acid (or carbonic anhydride, CO_2 according to more recent nomenclature) The lime and the carbonic acid are termed the *proximate* elements of calcic carbonate They admit of further separation into their *ultimate* elements, namely, the lime into the metal calcium and oxygen gas, and the carbonic anhydride into carbon and oxygen gas And of course, the lime and the carbonic anhydride are as unalterable in their composition as the calcic carbonate, or any other true chemical compound The lime contains 71 43 per cent of calcium, and 28 57 per cent of oxygen, while the carbonic anhydride contains 27 28 per cent of carbon, and 72 72 per cent of oxygen

According to the law of multiple proportions, when one element B unites with another element A in more proportions than one, the quantity of B increases in multiples, or in some other similar mode, such as—

A + B, A + 2 B, A + 3 B, A + 4 B, and so on.
Or, 2 A + 3 B, 2 A + 5 B, 2 A + 7 B, and so on
Or, A + B, A + 3 B, A + 5 B, and so on

For example, nitrogen and oxygen combine to form five chemical compounds, in all of which the proportion of nitrogen remains constant, but that of oxygen is a constantly increasing multiple of its atomic weight In the following table the first column contains the names of the compounds in question, the second the proportions of oxygen, and the third those of nitrogen —

Nitrous oxide,	16	28	Peroxide of nitrogen,	64 (16 × 4)	28
Nitric oxide,	32 (16 × 2)	28	Nitric anhydride,	80 (16 × 5)	28
Nitrous anhydride,	48 (16 × 3)	28			

If we take the percentages of the constituents of the above compounds, the above numbers will be obtained in each case by means of a simple proportion The first column of the following table contains the symbols of the above-named compounds, the second the percentages of oxygen, the third, those of nitrogen, the fourth, the equivalent weights of oxygen, and the fifth, those of nitrogen —

N_2O	36 36	63 64	16	28
N_2O_2 } Or, NO	53 33	46 67	32	28
N_2O_3	63 15	36 85	48	28
N_2O_4 } Or, NO_2	69 56	30 44	64	28
N_2O_5	74 07	25 93	80	28

The third law, or the law of atomic, or equivalent proportions, is this —That each element, in combining with other elements, or in displacing other elements from combination, does so in a fixed proportion, which may be stated numerically. For example, if a slip of copper be introduced into a solution of mercuric chloride, portions of the two metals change places, since chlorine has a stronger affinity for copper than for mercury, cupric chloride is formed, and mercury deposited. For every 31.7 parts by weight of copper dissolved, 100 of mercury are separated. So also, if into a solution of cupric chloride a strip of zinc be immersed, copper is separated. For every 31.7 parts by weight of copper thrown down, 32.5 parts of zinc will enter into solution. If a rod of zinc be immersed in dilute hydrochloric acid, hydrogen will be liberated, and for every 32.5 parts by weight of zinc dissolved, 1 part by weight of hydrogen gas will be set free.

By experiments of this kind it has been shown that different but definite weights of the various metals are capable of displacing each other. From the above examples it appears that 100 parts by weight of mercury, 31.7 of copper, 32.5 of zinc, and 1 of hydrogen, are each in a condition to supply the place of the other in combination with 35.5 parts of chlorine. These various weights are said to be chemically *equivalent* to each other, and numbers thus obtained are the *combining proportions* of the elements. But for the convenience of comparison, one element is chosen as the unit or standard. Such a unit is *hydrogen*, because it enters into combination with a lower equivalent weight than any other element.

Bodies then are said to be *equivalent* when they can be substituted for each other in combination, as in the above examples. But there are many compounds in which such a substitution is not possible, in such a case, the numbers attached to the elements represent, not properly *equivalents*, but *combining proportions*. (See *Atomic Weight, Atomicity*.) Under the last named heading, the *atom fixing* power of an element is explained. There is also (as we have seen above) an *atom-displacing* function. As many atomic units as an elementary atom can fix in a compound molecule it can, under proper conditions, displace. Thus, 1 part by weight of hydrogen in combination with 127 parts of iodine, forms 128 parts of hydriodic acid. In such a compound, the 127 parts of iodine may be replaced by 80 of bromine, or by 35.5 parts of chlorine. Now, when the I 127, the Br 80, and the Cl 35.5 are said to be equivalent to each other in chemical combination, the expression can only be allowed so long as those numbers represent the respective atomic weights of those elements. In this example the resulting compounds resemble each other in structure as they resemble the original compound of H and I, and it may not be improper to consider the atoms of I, Br, and Cl as equivalents, and also equivalent to an atom of H, although the respective weights are quite different.

ATOMIC VOLUME. Supposing the atoms of the elements to be identical in point of magnitude, then the specific gravities of simple solids would be in the same proportion as their atomic weights. This theory has led to the discovery of many interesting relations between the density of bodies and their atomic weights, but the subject is of too technical a nature to be exhibited within the compass of a few lines in a dictionary. The method of calculating the atomic weights (also called *Specific Volume*) of any substance, simple or compound, is to divide its atomic weight by its specific gravity. This gives the atomic volume or space occupied by the aggregates of atoms, as well as the interstitial spaces, the weight of the volume being proportional to the atomic weight of the body.

By the *Atomic Theory*, the atomic weight or its multiple shows the proportions in which one body combines with another by weight, so the atomic volume or its multiple shows the proportions in which one body will unite with another body by volume. Take an example from Watt's Dictionary of Chemistry, where subjects of this kind are treated with great power. The atomic volume of iodine is thus found —127 is the atomic weight, and 4.95 the specific gravity, then $\frac{127}{4.95} = 25.7$ the atomic volume, while in the case of silver, $\frac{108}{10.4} = 10.2$ the atomic volume of silver, whence it is inferred that 25.7 volumes of iodine unite with 10.2 volumes of silver to form iodide of silver Ag I.

ATOMIC WEIGHT. In contriving the *Atomic Theory*, Dalton supposed each element to consist of indivisible atoms (*Atom*), and that compounds were formed by the union of two or three or more of such atoms, which naturally leads to *definite* and *multiple* proportions. But the assumption on which the atomic theory rests, although a useful instrument in the pursuit of knowledge, is not knowledge, for knowledge is (1) the *belief*, (2) in what is *true*, (3) on sufficient *grounds*. But the grounds are not sufficient to justify the position that the elements are composed of indivisible atoms. The chemical evidence for such a statement is wanting, for although the assumption that indivisible particles, so minute as to elude observation, combine particle with particle, explain the phenomena, yet the assumption of particles in this proportion, and not indivisible, also do the same.

It must not, therefore, be insisted on, that the number attached to each element expresses the weight of its atom as compared with *hydrogen*, the least ponderous of all the simple bodies Nevertheless, while Dalton's great discovery of the atomic theory was admitted by every philosophical chemist, the doctrine of atoms was by no means passed with a unanimous vote It was proposed by Davy to bridge over the difficulty raised as to atoms by the term *proportion* or *proportional* This proposal was more or less adopted, and the word *atom* gradually came to be used in a sense that expressed no opinion as to the weight of the ultimate particle of any one of the elements, but it rather implied the smallest combining proportion of a body, and that, not in the sense of indivisibility, since *half* an atom is frequently referred to The retention of the word *atom* has in this way led to no confusion, since it is now admitted that the proportional number attached to each element is an unexplained property of matter The symbol attached to each element expresses one atomic proportion of the element in question, Cl being equal to 35 5 parts by weight of chlorine as compared with hydrogen, N equal to 14 parts by weight of nitrogen, Na to 23 of sodium, and so on Compounds are expressed by groups of symbols, NaCl (or common salt) shows that 23 parts of sodium unite with 35 5 of chlorine, while $AsCl_3$ shows that 1 proportional of arsenium = 75, combines with 3 proportionals of chlorine, = 105 5, the atomic weight of the compound being the sum of the atomic weights of the constituents

ATROPINE The active principle of the deadly nightshade (*Atropa Belladonna*) It is an organic alkaloid It crystallises in thin colourless needles, readily soluble in alcohol, slightly so in water Its taste is very bitter, and it is highly poisonous Atropine forms crystallisable salts with acids

ATTRACTION (*Attractio*, from *ad*, to, and *traho*, to draw) The tendency of certain bodies to approach one another Attraction is of two kinds, either taking place between bodies at an appreciable distance, or between particles at an inappreciable distance Gravitation is of the former kind, the molecular attractions of cohesion, magnetism, electricity, of the latter The mathematical investigation of these laws forms a branch of applied mathematics, termed the Calculus of Attraction, which may be said to have been founded by Newton In the *Principia* the following propositions are proved —A particle outside a sphere, which is either homogeneous, or consists of concentric spherical shells of uniform density, will be attracted in the same manner as if the whole mass were collected at the centre of the sphere A particle placed within a homogeneous spherical shell of small thickness, will be equally attracted in all directions The propositions were extended to ellipsoids by Poisson The history of this branch of mechanics since the time of Newton will be found in a memoir by Charles, *Sur l'Attraction des Ellipsoides* The following may also be consulted for the theory of attraction — Duhamel's *Cours de Mecanique*, Liouville's *Journal de Mathématiques*, tom vii, Professor Stokes' papers in Cambridge and Dublin Mathematical Journal, vol iv

ATTRACTION AND REPULSION, MAGNETIC When two dissimilar portions of magnetic matter are presented to each other—that is, when north and south magnetism are brought near to each other—*attraction* takes place, when two similar portions are presented *repulsion* is exhibited The quantitative law is expressed as follows (See *Magnetism*) Let unit force be exerted between unit portions of magnetic matter, placed at unit distance, then the force between any masses m, m' placed at a distance d from each other, is found by multiplying the number m, m' together, and dividing by the square of d. If f be the force then

$$f = \frac{m \times m'}{d^2}$$

and if the algebraic signs (+) and (—) be prefixed to the quantities m, m', then there will be repulsion or attraction between the masses according as the sign of f is positive or negative (See also *Magnetism*, *Magnet*, *Unit Pole*)

ATTRACTION AND REPULSION, ELECTRIC See *Electrostatics*

ATTRACTION AND REPULSION, ELECTRODYNAMIC See *Electrodynamics*

ATTRACTION, CHEMICAL See *Affinity*

ATTWOOD'S MACHINE A machine devised by Attwood for testing experimentally the laws of motion, and the results derived from the theory of falling bodies It consists of an upright beam, usually about 6 or 7 feet high, supporting at the upper extremity a nicely constructed wheel turning on a horizontal axis, and two equal weights connected by a fine silk thread, which passes over a groove in the wheel To diminish friction, the axis of the larger wheel turns on friction wheels The pillar is furnished (1) with a graduated scale of feet and inches, on which can be perceived the space passed through by the weight in a given time, (2) a moveable ring through which the weight on one side descends when in motion, (3) a stage which can be screwed to stop the weight at any time, (4) a small clock with pendulum beating seconds

At first, since the two weights are equal, they will be at rest A small moveable bar is then placed on one of them so as to cause it to descend The velocity of the moving weight continues to increase until it reaches the ring, here the bar is lifted off, and the weight then moves onward with a uniform velocity equal to that which it had at the instant when the bar was retained by the ring By making several trials, and listening to the ticking of the clock, while watching the space passed through, the stage may be fixed so as to stop the weight exactly one second after it has passed the ring The distance between the stage and ring is then the measure of the velocity acquired by the weight and bar in falling through the height above the ring If the time of descent to the ring be one second, then the distance between stage and ring measures the acceleration Thus Attwood's machine furnishes a means of causing the motion of a body by means of a determined pressure and cutting off the force producing motion at any point, at the same time allowing the body to continue its motion with the velocity acquired Hence all the laws of motion with uniform acceleration may be verified experimentally The following relation is found to exist between the acceleration and the weights — By doubling the weight of the bar, and keeping the larger weights the same, we double the acceleration, and always we increase the acceleration in proportion as we increase the weight of the bar If we keep the bar the same, but double the weight moved, we diminish the acceleration one half, and, generally, as we multiply the whole weight moved, we divide the acceleration Thus, the acceleration varies directly as the pressure, and inversely as the mass moved (See *Laws of Motion*) One important advantage secured by Attwood's machine is, that we may make the acceleration as small as we please by making the sum of the weights large, and their difference sufficiently small, and thus render the motion slow enough to be observed without difficulty (See *Falling Bodies*)

AURA ELECTRICA (*Electric Breeze*) A name sometimes applied to the currents of air which proceed from a point connected with a charged body, such as a needle attached to the prime conductor of an electric machine which is being worked The existence of these currents of air can be easily felt on bringing the hand or the face near to the point, or shown by placing a lighted candle in front of it The flame is powerfully repelled, and the candle may even be blown out Several electric toys are constructed to take advantage of these currents Thus, in the electric mill, a small wheel, furnished with paper vanes, is turned by means of it, or a piece of wire, with its points bent at right angles, and balanced on a point upon the prime conductor, revolves on the same principle as does Barker's hydrostatic reaction wheel

AURIGA In astronomy (*the Charioteer*), one of Ptolemy's northern constellations It contains the bright star Capella, and is crossed by the Milky Way

AURORA BOREALIS, or *Northern Light*, or, as it is more properly called, *Polar Light*, there being also an *Aurora Australis* A well known luminous phenomenon which is always accompanied by powerful disturbances of terrestrial magnetism and electricity We extract the following excellent description, by Humboldt, from De La Rive's Treatise on Electricity, where very full details on the subject may be found

"An Aurora Borealis is always preceded by the formation in the horizon of a sort of nebular veil which slowly ascends to a height of 4°, 6°, 8°, and even to 10° It is towards the magnetic meridian of the place that the sky, at first pure, commences to get brownish Through this obscure segment, the colour of which passes from brown to violet, the stars are seen as through a thick fog A wider arc, but one of brilliant light, at first white, then yellow, bounds the dark segment Sometimes the luminous arc appears agitated for entire hours by a sort of effervescence and by a continual change of form before the rising of the rays and columns of light which ascend as far as to the zenith The more intense the emission is of the polar light the more vivid are its colours, which from violet and bluish white pass through all the intermediate shades to green and purple red Sometimes the columns of light appear to come out of the brilliant arc mingled with blackish rays similar to a thick smoke Sometimes they rise simultaneously in different points of the horizon, they unite themselves into a sea of flames, the magnificence of which no painting could express, and at each instant rapid undulations cause their form and brilliancy to vary Motion appears to increase the visibility of the phenomenon Around the point in the heaven which corresponds to the direction of the dipping needle produced, the rays appear to assemble together and to form a boreal corona. It is rare that the appearance is so complete and is prolonged to the formation of the corona, but when the latter appears it always announces the end of the phenomenon The rays then become more rare, shorter, and less vividly coloured Shortly nothing further is seen on the celestial vault than wide motionless nebulous spots pale or of an ashy colour; they have already disappeared when the traces of the dark segment whence the appearance originated are still remaining on the horizon"

A French Scientific Commission in 1838-9 examined the phenomenon at Bosekop, lat 70° N,

and their results are published by MM Bravais and Lottin, two of the members, in the Arch des Sc Phys We regret that our limits will not permit us to insert their description of this wonderful phenomenon as seen in northern regions It appears that the aurora is seldom wanting there, in fact, that it may be assumed to exist every night but with varying intensity Before the occurrence of an aurora, and after its disappearance, the magnetic needles are observed to be strongly and steadily affected While it is going on sudden and powerful perturbations take place This may be beautifully seen by using a very light and small needle, such as that suspended in a Thomson's galvanometer The needle is kept in a state of perpetual agitation, generally speaking, at each pulsation of the light it starts in one direction traversing a space of several degrees Telegraph wires are also frequently affected to such an extent that the sending of messages is for the time being impossible

It is thus certain that the phenomenon has an electric origin De La Rive first propounded the theory that it is due to discharges of electricity taking place through the highly attenuated air at a distance from the earth, and to illustrate it he devised a beautiful experiment, in which the electric light in a Geissler's tube is shown to take a rotatory motion round the pole of an electro magnet similar to the motion observed in the Aurora Borealis from east to west Mr Balfour Stewart supposes that auroræ and earth currents are secondary currents due to changes in terrestrial magnetism

Sabine showed that there is a period of greatest frequency for magnetic storms and for auroræ, and that this period is coincident with that of the maximum appearance of the sun's spots

AURORA BOREALIS, SPECTRUM OF J A Angstrom has observed the spectrum of the Aurora Borealis, and finds it to be almost mono-chromatic, consisting of a single bright line to the left of the well known group of calcium lines With a wide slit traces of three other bands are also seen (See Poggendorff's *Annalen*, May 1869) Professor Winlock, examining the auroral spectrum, found it to consist of four green lines and one blue one Three of the green lines coincide with lines seen in the spectrum of the corona, as observed by Professor Young during the total solar eclipse of August 1869 (See *Spectrum*)

AURUM MUSIVUM See *Tin, Sulphides*

AUTUMN (*Autumnus*) In astronomy the time occupied by the sun in passing from the autumnal equinox to the winter solstice As the earth is in perihelion near the time of the winter solstice, her motion during autumn is swifter than during the two preceding seasons—spring and summer Hence the duration of astronomical autumn is less than one fourth of a year Its exact length, at present, is 89 days 16 hours, and 47 minutes (See *Seasons*)

AUTUMNAL EQUINOX The time at which the sun passes from the northern to the southern side of the equator (See *Equinox, Equinoctial, Libra*, &c)

AUTUMNAL POINT One of the points in which the ecliptic crosses the equator At this point the ecliptic—taken in the order of the signs—passes from north to south of the equator The point is also called the *first point of Libra* (See *Libra*)

AVENTURIN QUARTZ See *Quartz*

AVOGADRO'S LAW This law asserts that equal volumes of different gases, at the same pressure and temperature, contain an equal number of molecules It was propounded by Signor Avogadro, whose name is also well known in connection with experiments on the tension of the vapour of mercury Quite recently Professor Neumann has deduced the law mathematically from the first principles of the mechanical theory of gases (See *Berichte der Deutschen Chemischen Gesellschaft zu Berlin*, p 690 1869)

AXIS, MAGNETIC, is generally defined to be the line joining the poles of a magnet As, however, the word pole is used very indefinitely, we quote the following explanatory definition from a paper by Sir W Thomson on the mathematical theory of magnetism (Phil Mag 1851) "Conceive a magnet to be supported by its centre of gravity and left perfectly free to turn round this point If the body be placed in a position of equilibrium there is a certain axis such that if the body be turned round it through any angle and brought to rest, it will remain in equilibrium If the body be turned through 180° about an axis perpendicular to this, it will again be in a position of equilibrium Any motion of the body whatever which is not of either of the kinds just described, nor compounded of the two, will bring it into a position in which it will not be in equilibrium" The axis so described is called the magnetic axis of the body

AXIS OF AN ORBIT The major axis of a planet's orbit is the *apsidal line* (*q v*), the minor axis is a line at right angles to the former through its middle point

AXIS OF CRYSTALS See *Crystals, Optic Axis of*

AXIS OF LENSES The axis of a lens is a line passing through the centre of its curved surface or perpendicular to its plane surface

AXIS OF A PLANET The imaginary line upon which the planet rotates

AXLE (Saxon, *æx*, Danish and Swedish, *axel*) A piece of timber or bar of iron fitted for

insertion in the naves of wheels The axles of the wheels of ordinary vehicles are fixed, and the wheels rotate upon them, but in railway carriages the axles rotate with the wheels, and both form one piece The extremities of the axles project beyond the wheels and support the *bearings* of the carriage

AXLE, WHEEL AND See *Wheel and Axle*

AZALEINE Another name for Rosaniline, the base of one of the aniline dyes See *Aniline*

AZELFAFAGE. A star in the constellation Cygnus It is now inconspicuous, but was probably once a bright orb It is lettered π^1 in the nomenclature of Bayer

AZIMUTH (Arabic) In astronomy the azimuth of a celestial body is the angle between two planes, through the station of the observer, one passing through the zenith and the body, and the other passing through the zenith and the north and south points of the horizon Azimuths are measured through 180°, and in general from the north or south point of the horizon, according as the north or south pole of the heavens is above the horizon

AZIMUTH CIRCLES The same as *Vertical Circles, q v.*

AZIMUTH COMPASS See *Compass*

AZOTE See *Nitrogen*

AZOTIC ACID See *Nitric Acid.*

B

BACK STROKE See *Return Stroke*

BALANCE (*Bilanx*, having two scales, from *bis*, twice, and *lanx*, a scale or plate) One of the simplest applications of mechanical principles belonging to the first great class of machines. (See *Mechanical Powers*) It is a lever of the first kind, the fulcrum being between the power and the weight It is commonly used to ascertain the weight of bodies in comparison with the standard units of weight The ordinary balance consists essentially of a metallic bar or lever, called the beam, either delicately suspended, or supported on a stand by the intervention of a wedge-shaped prism, technically termed a knife edge, exactly at its middle point An index is fixed at right angles to the beam, and made to travel over a graduated arc, so as to show when the beam is horizontal A scale-pan is suspended from each end of the lever Since the arms of the balance are equal, it is plain that there cannot be equilibrium unless the weights placed in each scale are equal (See *Lever*) When this is the case, the beam is perfectly horizontal, and the index vertical The balance is then said to be true When the beam is horizontal with unequal weights, the balance is false Thus it is easy to test the truth of a balance by first placing in the scales weights which apparently are equal, and then transferring each into the other scale If the weights are not really equal, one of them will appear heavier than the other after the transfer There are, however, two methods of finding the exact weight of a body by means of a false balance The body may be weighed with standard weights in each scale successively, and the true weight is the mean proportional between the two apparent weights Thus, if a body appears to weigh 4 lbs in one scale, and 9 lbs in another, its real weight is 6 lbs Or the body (placed in one scale) may be balanced by a sufficient quantity of any convenient substance, sand, for instance, so that the beam is horizontal, and then replaced by standard weights until the sand is balanced, the weight thus obtained is the true one

The requisites of a good balance are these —(1) It should have its beam in stable equilibrium (see *Equilibrium*), for which purpose the centre of gravity of the beam and its appendages should fall a little below the knife edge (2) Both when the scales are empty, and when equal weights are placed in them, the beam should be horizontal and the index vertical, the arms, of course, being exactly equal to one another (3) It is of great importance that the balance should be very sensitive, and indicate very slight inequalities in the weights The sensibility of a balance becomes greater (*a*) as the length of the arms is increased, which augments the difference in moment about the fulcrum, due to difference of weight, (*b*) as the weight of the beam is diminished, for, when the beam is displaced by the inequality of the weights, its own weight gives it a tendency to return to its first position But this displacement is less for a given inequality in the weights as the weight of the beam is increased, so that the less the beam weighs, the more sensitive it becomes

A form of balance, more convenient for counterpoising, but less exact than the common form, is that in which the scale-pans are placed above the beam For other balances having unequal arms, &c, see *Steelyard*

BALANCE, BIFILAR, or BIFILAR MAGNETOMETER First constructed by Sir W Snow Harris, and improved by Weber and Gauss, consists of a bar magnet suspended horizontally by two equal vertical fibres or wires, which are accurately adjusted so as to divide the weight of the bar equally between them. When the bar turns, the fibres become inclined to the vertical, and the bar is raised. If, then, the tension of the fibres be neglected, the measure-

ment of the force tending to turn the magnet is made by comparing it with the weight of the bar itself In order that the deflections, which are very small, may be read from some distance, and with very great accuracy, Weber and Gauss attached to the bar a plane mirror, and placed a scale opposite to it, at some distance from it The divisions of the scale reflected in the mirror are read off by means of a telescope, and by this means it is of course easy to calculate the angle through which the magnet has turned The principle has been adopted in magnetic observatories A full description of Sir W S Harris' balance is to be found in the Transactions of the Royal Society for 1836

BALANCE OF ROBERVAL A balance composed of a jointed rectangle, the middle points of two opposite sides of which are attached to two fixed joints in the same vertical line, the other two opposite sides having two exactly equal bars attached perpendicularly to these sides at their middle points When equal weights are suspended from the arms, they will always balance each other wherever may be the points of suspension The instrument was devised by Roberval, a French mathematician of the seventeenth century, to illustrate the seeming paradox of equal weights balancing each other with unequal arms The first to give a full explanation of the phenomenon was Poinsot, who applied to it the theory of couples, of which he was the discoverer (See Poinsot's *Éléments de Statique*)

BALANCE, TORSION This instrument was invented and used by M Coulomb for the purpose of investigating the laws of electric attraction and repulsion, and of the distribution of electricity upon the surface of a conductor It was afterwards employed by Faraday in a slightly modified form in his celebrated experiments on statical electricity, and as this is the form in which it is now generally used we shall so describe it The exterior case of the instrument is a hollow cylinder of glass about 9 inches in diameter and 8 inches high placed with its axis vertical on a convenient mahogany plate which is furnished with levelling screws The top of the cylinder is covered with a circular glass plate, in the centre of which a round hole is cut In this hole is inserted the extremity of a glass tube 0 8 inches in diameter and 16 inches high, and the upper part of the tube is closed with a circular mahogany cap, the top of which is divided into degrees A thin bar passes downwards through the middle of the cap and is capable of turning in its socket, and it has a pointer which moves over the graduated circle attached to its upper end To the lower end is fastened a very fine thread of glass which passes vertically down through the tube into the glass cylinder And this carries a light arm of glass or of shell lac which swings horizontally in the glass cylinder, being furnished at one end with a light gilded ball of elder pith and at the other with a counterpoise The length of the horizontal arm is but little less than the diameter of the glass cylinder If now any force be applied to turn this arm it is resisted by the force of torsion of the glass fibre by which it hangs, and according to Hooke's well known law, *ut tensio sic vis*, the angle through which the arm is turned is simply proportional to the force applied The angle is read off on a scale pasted round the body of the cylinder on a level with the moveable arm Through another hole cut in the covering plate of the cylinder an electrified body can be let down This is generally a second gilded pith ball insulated on a shell lac stem and exactly similar to the first, and the hole in the cover is arranged so that the pith ball when in its place shall be opposite zero on the scale just mentioned The use of the instrument is readily understood from what has been said For if the swinging, or, as we may call it, the moveable ball be brought opposite zero on the lower scale, and the second pith ball be electrified and introduced into its place, on contact taking place the two balls will be similarly electrified, and will repel each other to a certain distance The force with which they repel is calculated by observing the angle of torsion By now turning the bar at the top from which the glass fibre is suspended the distance is altered and the force of repulsion also, the amount of this repulsion is again determined from the angle of torsion To examine the force of attraction the moveable ball is electrified and then turned from zero to a certain position On introducing the second ball into its place charged with the opposite kind of electricity attraction takes place, the amount of which may be determined in a similar way

BALANCE WHEEL A contrivance for producing the same regulating effect in watches and in marine time-pieces as the pendulum in clocks Since the pendulum must be fixed at some stationary point in order to vibrate, it cannot be used for those chronometers which are to work while carried about either on land or at sea, and for these some regulator is required which will not be disarranged by a change of position Such an instrument is found in the balance wheel Just beneath this wheel a very fine steel spring, much smaller than the main-spring, is attached by one end to the central part of it, and by the other to some suitable point near the rim of the wheel When the spring is drawn aside it tends to return to its normal form, and by the velocity acquired in this recoil it passes to an equal distance on the opposite side of its original position Thus its oscillations become isochronous for reasons analagous to

those in the case of the pendulum The balance-wheel is connected with the general system of wheel work in the watch, and is therefore moved from rest by the mainspring (an escapement wheel being interposed) Consequently its isochronous oscillations are produced at the same time as the other movements, and so regulate the motion of the whole system of wheel work (See *Horology*, *Pendulum*, *Isochronism*)

BALL AND SOCKET (*Socket*, an opening into which anything is fitted, diminutive of *sock*—a form existing in all the languages of Western Europe, denoting a covering for the foot, especially *lat socrus*, the low-heeled shoe worn by comic actors, in contrast to the buskin worn in tragedy) A description of joint used for connecting parts of machinery so as to allow one of the parts to move in any direction The connected parts are usually two rods, one of which has a solid spherical metallic ball attached to its extremity, and the other a hollow sphere or *socket*, the internal diameter of the socket being exactly equal to the external diameter of the ball, so that the latter exactly fits the former The socket is not complete, but consists of so much of the sphere as is necessary to prevent the ball from being pulled out of it (See *Joint*)

BALLISTIC PENDULUM (Robin's) (*Ballistique*, pertaining to projectiles, βάλλειν, to throw) This is a machine used to ascertain the velocity with which a shot leaves the mouth of a cannon In its simplest form it consists of a large block of wood suspended from a *knife edge* in front of the mouth of the cannon, having some means of measuring the angle through which the beam oscillates The wood is plated on the outer side with iron When the shot is fired into the mass it lodges there, and causes it to move through a certain angle When the magnitude of this angle is known, together with the centres of suspension and oscillation of the mass, the velocity of the shot can be determined by calculation

BALLOON (*Ballon*, a little ball) A machine which, filled either with heated air, or with gas specifically lighter than the atmosphere, can float in the air, supporting at the same time a greater or less weight

Montgolfier made the first balloon in 1783 It was a fire-balloon—that is, the air within it was heated and so rarefied Fire balloons are too unsafe, however, to be trusted by aeronauts, and the common practice now is to employ a light gas (carburetted hydrogen) The balloon is only partially filled, because, as it rises, and the pressure of the air diminishes, it would burst had it been actually filled at a lower level

For the history of ballooning, the reader is referred to Hatton Turnor s *Astra Castra*

Recently Mr Glaisher has made several ascents in Mr Coxwell's balloon, for the purpose of investigating the condition of the upper regions of the air He has in this way been enabled to add importantly to our knowledge of the laws which regulate the temperature of the air at different levels, besides obtaining an insight into the characteristics of the various orders of clouds, which no amount of study by observers at the earth's surface could possibly have secured One of his ascents with Mr Coxwell was specially remarkable, as indicating the extreme limits of height to which men can hope to attain In this ascent, when the balloon had attained a height of nearly 6 miles, Mr Glaisher became insensible Mr Coxwell, after endeavouring to rouse Mr Glaisher, found that he was himself losing his strength Indeed, he was unable to use his hands, and had he not succeeded in pulling the valve string with his teeth, he and his companion must inevitably have perished The height attained before the string was pulled, would seem, from an observation made by Mr Coxwell, to have been about 6½ miles At this time the temperature was 12 degrees below zero, and the neck of the balloon was covered with hoar frost

It is worth noticing, however, that, although it would seem from this experience that no one accustomed to breathe the air at ordinary levels can hope to attain a greater height than 6½ miles, it is not impossible that those who pass their lives at a great height, as the inhabitants of Potosi, Bogota, and Quito, might safely ascend to a far greater height We know that De Saussure was unable to consult his instruments when he was at no higher level than these towns, and that even his guides fainted in trying to dig a small hole in the snow, whereas the inhabitants of the towns thus exceptionally placed, are able to undergo violent exercise We may assume, therefore, that their powers are exceptionally suited to such voyages as those in which Glaisher and Coxwell so nearly lost their lives

BARIUM (βαρύς, heavy) The metallic basis of the earth baryta, which latter body was first recognised as a distinct substance by Scheele in 1774, the metal being obtained by Davy in 1808 Its symbol is Ba, and atomic weight 68 5 It is of a silver-white colour, rapidly oxidising in the air The most important compounds are as follows —*Oxide of barium* or *baryta* (Ba_2O), prepared by igniting nitrate of barium (See *Nitrates*) It is a greyish-white friable mass of specific gravity 5 54, soluble in water, forming a strongly alkaline solution Sprinkled with a small quantity of water, it forms a white hydrate, with great evolution of heat and expansion

of volume, its formula is BaHO, when dissolved in water and crystallised, it separates in transparent colourless prisms, which contain four atoms of water

Peroxide of Barium (BaO), a gray powder formed when baryta is heated to dull redness in air, or oxygen At a strong red heat it gives up this additional quantity of oxygen, and hence has been proposed by Boussingault as a means of extracting oxygen from the air Peroxide of barium is slightly soluble in cold water, it is readily decomposed with evolution of the extra equivalent of oxygen

Chloride of Barium (BaCl), forms transparent colourless tabular crystals which contain water It dissolves readily in water, slightly so in strong acids, and is almost insoluble in alcohol For other salts of barium, see the respective acids

Barium compounds heated before the blow pipe communicate a beautiful green colour to the flame (See *Coloured Flames*)

BARKER'S MILL, or, *Segner's Wheel* Since every equal unit of surface of a vessel full of water is subject to a pressure proportional to the depth of the unit below the surface (see *Pressure through Liquids*, also *Lateral Pressure of Liquids*), every unit of surface at the same depth is equally pushed outwards For each such pressure on one side of the vessel there is an equal and opposite pressure on the other, whereby the whole vessel is kept in equilibrium. If one such unit of area be removed—that is, if a hole be cut in the side of a vessel of water—the water in flowing out will no longer be able to press upon the surface which has been removed, but will nevertheless continue to press with equal force on the opposite unit of area The consequence will be that the vessel will be urged in the direction opposite to that in which the water flows out Barker's Mill in its simplest form consists of a ⊥-shaped tube, the stem of which is vertical, and the cross-piece downwards The ends of the cross-piece are closed, the end of the vertical tube is open The whole is supported on a pivot at the joint where the two tubes meet one another If such a tube be filled with water, it will remain at rest If, however, openings be made, one on one side of one limb of the lower tube, and the other on the opposite side of the other limb, water will flow out of both of these openings, and the corresponding pressures on the other sides of the two limbs will cease to be counterbalanced Being on opposite sides of the pivot, and on opposite sides of the tube, they will assist one another in turning the whole instrument round on the pivot This motion is continuous, provided the open upright tube be continually supplied with water By increasing the number of cross tubes below, and having numerous holes in one sense in all of them, the total effect may be greatly increased, as also by increasing the height of the upright tube, and thereby the pressure of the water A practical objection arises from the great loss by friction when a long heavy tube of water rests on the pivot To remove this the water is sometimes, and with advantage, introduced from below

BAROMETER (βάρος, weight, and μέτρον, measure) An instrument invented in 1643 by Torricelli, for measuring the pressure of the air, one of the best known, as it is one of the most important of the scientific instruments used in our day The experiment by which Torricelli established the principle of the barometer may be thus described —

If a glass tube about 33 inches long be filled with mercury, and the open end plunged into a vessel of that metal, the column of mercury will be seen to sink till its surface is about 30 inches above the surface of the mercury in the open vessel The pressure of the air on the latter surface now balances the weight of the mercurial column For this column is kept in equilibrium by two forces only, its weight acting downwards, and the upward pressure exerted by that part of the mercury which lies in the tube on the same level as the surface in the bowl, and this latter pressure by the principles of hydrostatics is the same as the pressure on any equivalent portion of the exposed surface of the mercury Thus the height of the supported column affords a measure of the pressure exerted by the atmosphere

All mercurial barometers are constructed with the object of measuring this supported column of mercury There are two principal varieties—*cistern barometers* and *siphon barometers*

In the cistern barometer the Torricellian experiment is simply reproduced The object chiefly aimed at in all varieties of this instrument is the exact estimation of small changes in the height of the mercurial column. If the cistern be of a considerable cross section (horizontally) the fall of the column in the tube does not considerably affect the level of the free surface Still the change of level has to be taken into account in observations where exactness is required It is obvious that the height of the column of mercury must be measured from the level of the free surface at the moment of observation, so that a fixed scale would be useless for exact measurement, unless its divisions were so marked as not to represent true inches and aliquot parts of an inch, but the rise and fall of the barometric column in absolute height above the free surface Thus, suppose the column 30 inches high, and that it *seems* to fall one inch (measuring the fall by any ordinary rule, for instance), then the mercury in the cistern has been increased in

quantity and so has risen by a certain small amount, and therefore the real fall of the mercury has been less than one inch On the other hand, if the mercurial column had seemed to rise one inch, the real rise would have been more than one inch, for the free surface would have fallen Hence, if a fixed scale is used, without any contrivance for bringing the free surface to a fixed level, the so-called inch divisions must be greater than an inch below the division for which the free surface has its mean level, and less than an inch above that division Another method is to have a sliding scale, whose zero can be brought to the level of the mercury in the cistern But a more convenient plan (though the same in principle) is one by which the level of the free surface of the mercury can be brought to coincidence with the zero of a fixed scale In Fortin's contrivance for this purpose, the cistern is enclosed within a brass box, the sides of the cistern being of boxwood, its bottom of flexible leather A screw which works through the bottom of the brass box against the leather bottom of the cistern, enables the observer readily to shift the level of the mercury in the cistern A float carrying an index point, which must be brought opposite a fixed point on the scale, serves to show when the adjustment is complete , or an ivory needle is attached to the scale, with its point so placed as to be on a level with the zero point, and the mercury in the cistern is raised or lowered until the image of the needle's point coincides with the point itself

In Adie's *travelling barometer* the first of the three methods described above is employed, and to prevent the risk of breakage from the motion of the mercury within the tubes in carriage, the tube is narrowed along a part of its length In the *marine barometer* a similar plan is adopted, but the tube is narrowed through the greater part of its length In this form also, an air-chamber is formed at one part of the tube, so that air-bubbles accidentally introduced into the tube may be prevented from reaching the Torricellian vacuum, or from affecting the apparent length of the mercurial column

In *siphon barometers* there is no cistern, the tube being simply turned upwards at the lower end A graduated scale is so placed as to indicate the height of the mercury in each limb above a fixed zero The difference of readings gives the height of the mercurial column above the exposed surface The actual variation of the upper as well as of the lower surface of the mercury is but one half the variation in the height of the barometric column, for the latter variation is, in this form of the barometer, obtained by equal motions of ascent or descent in one tube, and of descent or ascent in the other

In the *wheel barometer* a thread attached to a float on the free surface of the mercury of a siphon barometer, passes over a pully and bears at the other end a weight almost exactly counterpoising the weight of the float An index on the axle of the pulley is moved across an arc on the face of a dial, as the float rises or falls This arrangement was invented by Dr Hooke Though very suitable for an ordinary weather glass, this form has no scientific value The thread varies in length with changes in the moisture of the air, and the friction of the different parts of the instrument acts uncertainly

Contrivances have been employed for increasing the range of barometric oscillations , but scientific men prefer to trust to the application of carefully divided scales

Corrections —Four corrections have to be applied to the barometer, used as a metereological instrument at a fixed station

The first is the correction for the height of the station above the sea level, and is calculable by the ordinary rules applicable to the estimation of heights by means of the barometer

The second depends on the circumstance that the surface of mercury in a narrow tube is not plane, but convex The following table exhibits "the correction for capillarity" (as this correction is called) for tubes of different diameter. It is taken from the Encyclopedia Britannica, Art "Capillary Action "—

Diameter of Tube Inches	Depression Inches	Diameter of Tube Inches	Depression Inches
·10	1403	40	0153
·15	0863	45	0112
20	0581	·50	0083
·25	0407	55	0044
30	0292	60	0023
35	0211	65	0012

It will be seen how largely the increase of the tube's diameter tends to diminish the correction for capillarity.

In the siphon barometer there is theoretically no correction for capillarity, as the correction for the surface in the open limb is equal to the correction for the surface in the closed limb, so that in taking the difference both corrections disappear This advantage is in great part counterbalanced, however, by the effect of the air in fouling the mercury in the open limb.

Thirdly, there is the correction for temperature It depends on the expansion of the mercury and of the scale of divisions But the latter expansion may commonly be neglected The expansion of the mercury may be assumed to be approximately one ten-thousandth part of its bulk for each degree Fahrenheit Hence, for reducing the observed height of the mercurial column to that which it would have were the temperature that of the freezing point, we have the rule—"Deduct the ten-thousandth part of the observed height for each degree of Fahrenheit above 32°

Fourthly, for certain applications of the barometer it is necessary to make a correction for the annual and diurnal range in the variation of atmospheric pressure (see *Atmosphere*), in order to determine how much the height exceeds or falls short of the estimated mean for the hour and date of observation

Employment of the Barometer —The barometer is employed in many important departments of science The astronomer employs the barometer to determine the amount of correction he is to apply for atmospheric refraction In geodesy, for a similar reason, the barometer is an important auxiliary In many chemical researches its use cannot be dispensed with Its use in the measurement of heights need not here be considered

As a means of prognosticating the weather the barometer is of great utility, especially at sea But its value for this purpose depends largely on the intelligent combination of its indications with those of other instruments (See *Weather Prediction*)

BAROMETER, ANEROID (α, without, and νηρός, moisture) The mercurial barometer necessitates an instrument of at least 32 inches in length In the aneroid barometer, or barometer without liquid, this inconvenience is overcome In such barometers, the atmospheric pressure is held in equilibrium by an elastic metallic spring A metallic box, having one flexible side, is completely exhausted of air, and sealed The elasticity of this side of the box, and the atmospheric pressure thereon, keep one another in equilibrium The short arm of a lever is kept continually pressed upon the elastic side, and the other arm works an index similar to that of the weather glass When the atmospheric pressure increases, the box is partly crushed in, when it diminishes, the elastic side recovers its shape, and the index moves in the opposite direction

Sometimes a box of elastic metal, in the shape of a horse-shoe, is employed One end of this being fixed, the general curvature of the box is affected by the atmospheric pressure, and the consequent motion is exhibited at its maximum at the other (or free) end, which, as in the former case, is connected by a lever with a moveable index Though very convenient, and, for short intervals of time, quite trustworthy, the aneroid barometer, of whatever form, requires frequent comparison and correction from a standard mercurial barometer, because the metal "sets" on account of its imperfect elasticity

BAROMETER, DESCARTES' In order to magnify the effect of the mercurial barometer, Descartes proposed to use a mixed column of mercury and some lighter liquid in the following way —The top of the mercurial barometer was enlarged into a wider cylinder of uniform bore, and again contracted into a tube of the ordinary size The top of the mercury column was in the widening Above this, and reaching up into the narrow tube, was water, or a solution therein of tartrate of antimony and potassium It is clear that if the atmospheric pressure increase, say a quarter of an inch, the mercury in the wider cylinder would rise to that amount if no liquid were above it It will therefore squeeze up the lighter liquid in the lighter and narrower tube (supposing this to have no weight) to an amount inversely proportional to the sections of the two columns Since the relative specific gravities of the water and mercury are known, it is easy to calculate the entire weight of the compound column Owing to the tension of the watery vapour, this form of barometer was abandoned By using glycerine and certain hydrocarbons of high boiling point and little vapour tension as the upper liquid, it is easy to construct a barometer which shows the variation in pressure due to one foot difference in height

The mercurial barometer is the most convenient for determining the actual weight of the atmosphere If we take a tube whose sectional area is one square inch, close it at one end, fill it with mercury, and invert it into mercury, we shall find that the difference of level between the inner and outer mercury is about 30 inches Take a column of mercury 30 inches high, and of one square inch sectional area, and we find that it weighs about 15 lbs Hence it follows that the pressure of the atmosphere is 15 lbs on the square inch of surface

BAROMETER, WATER A barometer in which water is used instead of mercury As mercury is nearly 14 times heavier than water, the column of the water barometer is nearly 14 times higher than the mercurial column (see *Barometer*), or nearly 35 feet long, all changes of elevation would also be proportionately greater But as the space above the water column would be filled with aqueous vapour, varying in tension with temperature, the water barometer would not be a satisfactory weather indicator.

BAROMETRIC LIGHT When an upright barometer is moved gently backwards and forwards from the vertical to an oblique position, so as to make the mercury oscillate in the tube through a range of a few inches, the Torricellian vacuum becomes lighted up so as to be visible in the dark. This is called the *barometric light*, and is due to electricity arising from the friction of the mercury against the inner surface of the tube Mr Tomlinson has described an experiment in which the phenomenon is exhibited on a large scale in the vacuum of an air pump. The chief precaution is, that the mercury and the glass apparatus be quite dry Hence the experiment succeeds best in frosty weather

BARTON'S BUTTONS, or, *Iris Ornaments* By means of a dividing engine, Mr John Barton succeeded in engraving lines on steel and other surfaces not more than from the 2000th to the 10,000th of an inch apart These, owing to the action of grooved surfaces on light, shine in the light of candles or lamps with all the colours of the spectrum From steel dies thus prepared impressions were stamped upon buttons and other articles, forming ornaments rivalling in colour the brilliant flashes of the diamond (See *Grooved Surfaces, Colours of, Interference of Light*)

BASE The definition of the word base is as difficult in the present state of chemical science as that of the word acid It may be considered as the converse of acid, or the body which, uniting with an acid, will form a salt (See *Acid, Salt*)

BATEN KAITOS, (Arabic and corrupt Greek) The star ζ in the constellation Cetus

BATTERY, ELECTRIC (First constructed by Winkler, 1746) An electric battery consists of a collection of Leyden jars whose outside coatings are all electrically joined together and likewise their inside coatings Practically it is usual to have a large wooden box divided off into partitions by means of thin wooden bars, each partition being capable of holding one jar. The bottom of the box is lined with tinfoil, and thus the jars, when placed upon it, have their outside coatings connected By means of a strip of tinfoil passing up from the bottom, and a stout brass wire passed through the side of the box, the outside coatings are all joined to a knob on the outside in some convenient position for discharging The inside coatings are all connected together by means of brass rods passing from knob to knob We obtain by this arrangement the same effect as from a single Leyden jar of, it may be, enormous dimensions But to procure a jar of unusual size is difficult, and such jars are both expensive, and being cumbrous, liable to get broken Hence a battery is always preferred. The jars are generally four, six, or nine in number, and each exposes from two to three square feet of tinfoil coating The amount of electricity accumulated is proportional, other things remaining the same, to the amount of coating, whether in one large jar or in a number of jars joined together as we have described them Very remarkable effects may be obtained by means of a good battery When charged it must be cautiously handled, for serious accidents, even endangering life, may readily occur For further information the articles on *Discharge* and on *Leyden Jar* may be consulted

BATTERY, GALVANIC, consists of an association of galvanic *pairs* or *elements* for the production of current electricity Any simple arrangement of metals and liquids for the purpose of producing a current of electricity, such for instance as a plate of zinc and a plate of copper immersed in dilute sulphuric acid, is called a galvanic element or a battery cell, and when several such cells are connected together so as to produce a greater effect the collection is called a battery The very simplest form of battery consists of a number of pairs, such as that which we have just mentioned, of copper and zinc, immersed in dilute sulphuric acid, the successive pairs are joined together by wires, the copper of the first cell to the zinc of the second, the copper of the second to the zinc of the third, and so on On connecting together the zinc of the first with the copper of the last we may obtain a very powerful current This form of battery was proposed by Volta, and is called *Volta's Crown of Cups* We are now acquainted with many forms more powerful than that composed of zinc and copper elements, and we shall describe the more important of them in their proper places Our limits will not, of course, permit us to enter into a description of all, even of the important ones, or into a very detailed description of any Such information must be obtained from a treatise on physics or on physical chemistry

A great objection to the use of the simple battery above described is found in what is called the *polarization* of the plates The current set up on connecting together the battery terminals very soon falls off in strength, the reason being that the plates assume a condition such as both to hinder further action and even to tend to produce a current in the opposite direction In fact, the hydrogen which is liberated at the copper surface not only hinders the contact of the fluid with the copper, but as it is produced in a state of high excitement, called the *nascent state* (see *Nascent State*), it has a great tendency to become oxidized again, and by its oxidation sets up a current opposite to that of the battery The effect of this is to diminish the primary current, and in many cases even to make it almost imperceptible, and it has been a great desideratum

with inventors to find some method of getting rid of this deposit of hydrogen For this purpose Smee's battery and Daniell's battery have been constructed, and we have described them under these names. We have also given an account of Bunsen's battery, Grove's battery, and the Menotti battery Besides these there are many other forms, such as the bichromate of potassium battery, the sulphate of mercury battery, the Leclanché battery, but these are all liable to the great objection of not being constant in strength, in most cases to such an extent that the current falls almost to nothing in a few minutes, and they can only be used for such purposes as ringing electric bells and the like, where a momentary current is enough

For further information on this subject see the articles on the various forms of battery, *Current, Electric*, *Plates, Polarization of*

BATTERY, MAGNETIC A magnetic battery consists of a number of magnets arranged together, so that by their conspiring action considerable force may be obtained Various forms of compound magnets, or magnetic batteries, have been proposed and used In general, they consist of a number of bars, each magnetized by itself, and all bound together with their similar poles towards the same parts Sometimes a number of straight bar magnets is put together round two parallelopipeds of soft iron, one at each end, which project from the bundle These soft iron pieces are the *armatures* of the compound magnet, and, becoming magnetized inductively, concentrate the force of the magnet to *poles* within themselves The whole bundle is kept together by bands of copper or brass, or occasionally by screws passing through the bars Batteries of the horse shoe form are also made by screwing together any number of similar horseshoe plates, each of which has been magnetized by itself The extremities of the compound magnet are made smooth and parallel, and a *keeper*, or soft iron bar, joining the poles, is constantly in contact with them when the magnet is not in use

BATTERY, THERMO ELECTRIC It is explained (see *Thermo electricity*), that when a circuit is formed containing two metals,—for example, bismuth and antimony,—and when one of the junctions is raised to a higher temperature than the rest, a current is generated, the direction of which depends upon the nature of the metals Thus, in the case of bismuth and antimony, the current passes from the bismuth to the antimony through the hot junction The electro motive force of a single pair is, however, very small, being estimated, according to a determination of Wheatstone, in the case of bismuth and antimony, in hundredths of a Daniell's element, for a difference of temperature of 180° F (100° C) In order to obtain considerable electro motive force for a small difference of temperature, an arrangement similar to that adopted in the case of the ordinary galvanic battery is made use of A large number of bars of bismuth and antimony are soldered end to end alternately, and are so bent that all the bars may be parallel, and all the alternate junctions may point the same way It will be seen that in such an arrangement, if one series of junctions be exposed to heat and the other to cold, the tendency at each junction is to send the current in the same direction, and the aggregate effect may thus be made considerable The electro motive force is, however, always low, and in order to make the current available in cases in which it is to be employed for measuring small differences of temperature, a galvanometer constructed of short thick copper wire, and called a *Thermo-multiplier* is used (See also *Thermo-pile, Thermo-multiplier*)

B A UNIT A contraction frequently used in speaking of the British Association Unit of Electric Resistance (See *Resistance, Units of Electric*)

BEATS If a note of permanent pitch be sounded continuously, and another note of graver pitch be gradually raised in pitch so as to reach and exceed the pitch of the first, a peculiar throbbing is heard consisting of rapidly recurring augmentations of sound as the two notes approach one another, the intervals of the throbs or "beats" become greater and greater as the two notes approach unison, when this point is attained, they cease As the second note surpasses the first, the beats recommence at first slowly, then more rapidly, until they cannot be distinguished from one another If one note consists of say 201 notes a second, and the other of 200, at the end of every second the 201st vibration of the first note will coincide with the 200th of the second, and consequently there will be 1 beat or augmentation per second When the second note has 202 vibrations a second, there will be 2 augmentations in the second, namely, at the half second, when the first note has completed its 50th vibration, and the second has completed its 101st vibration, and again at the end of the second Accordingly and generally, the number of beats heard in a second, when two notes are sounded together, is equal to the difference between the numbers of vibrations which they make in a second Hence, when the notes are very nearly of the same pitch, differing in pitch say $\frac{1}{2}$, 1, 2, 3, 4, 5, vibrations from one another per second, beats are heard at intervals of 2, 1, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{5}$, &c , seconds apart, these can be distinguished easily by the ear, and impart an agreeable additional rhythm to the compound sound If, on the other hand, the notes differ so widely in pitch that there is a difference of say 100 or 200 vibrations a second, there are 100 or 200 beats a second which cannot

be distinguished from one another, and which, if heard separately, would form a secondary note Between these limits, and especially when the difference of vibration is about 16 in a second, the beats constitute a harsh rattle, which is one cause of dissonance The discord or dissonance, however, between two notes, does not wholly depend upon the number of beats in a given time, but is lessened when the interval between the notes is increased

BELL. (Anglo Saxon, *bellan* to resound) A hollow, conical, musical instrument, which, when struck, emits a sound A bell, acoustically considered, acts like a disc during vibration—that is to say, it is divided into a certain number of vibrating segments, divided by nodes or points of comparative rest A circular bell during vibration alters its shape, and the mouth, instead of presenting the figure of a circle, is alternately an ellipse in one direction, then in a direction at right angles to its former position A bell divides itself into four vibrating segments, separated by four nodes, when it emits its deepest note, and the point where the hammer strikes the surface of the bell, is always the centre of a vibrating segment If a bell be placed with its mouth upwards, filled with water, and then caused to vibrate by drawing a violin bow across its edge, the vibrations are indicated by ripples on the surface of the water, and sometimes spheres of water are projected from the surface By using warm ether or alcohol in place of water, M Melde has produced some very beautiful effects, for the detached spheres, when they fall again to the liquid surface, do not immediately coalesce with it, but roll along it to the lines of rest This experiment may be tried with a finger glass or tumbler

Bells are usually made of an alloy consisting of 80 parts of copper and 20 of tin, small quantities of lead, zinc, and sometimes silver have been added, but without an increase of sonorousness The number of changes which may be rung on a given number of bells increases enormously with that number Thus, four bells produce 24 changes, while six bells produce 720, and twelve bells no less than 479,001,600 changes

BELLATRIX The star γ in the constellation Orion.

BELL, DIVING See *Diving bell*

BELLOWS (Anglo Saxon, *bylig*, a bag) A very ancient contrivance for producing a blast of air It consisted in its rudest form of a bag which was compressed, allowed to become full of air, again compressed, and so on Representations of bellows have been found among some of the earliest Egyptian sculptures, and Sir Gardiner Wilkinson believes that he has detected a valve as early as the time of Moses Ordinary bellows, as now used, are practically leather bags which are compressed, then expanded, so as to allow air to enter through a valve opening inwards, which, on compression of the bellows, allows no air to escape save through the nozzle In the case of a supply of air for large furnaces, the hot-blast for smelting iron, &c, a blowing machine is employed, in which a piston works in a large cylinder, and both by its upward and downward stroke ejects large quantities of air from the cylinder at an uniform pressure and velocity

BELTS A name applied to the faintly coloured streaks crossing the discs of Saturn and Jupiter The belts are supposed to be due to the existence of clouds in the atmosphere of a planet Trade-winds, resembling those which we are acquainted with, but flowing much more strongly, on account of the more rapid rotation of Jupiter and Saturn, would gather these clouds into zones These cloud-zones would appear white by reason of the high reflective power of the clouds, so that the space between them would appear as dark belts It has not perhaps been sufficiently considered that, despite the very rapid rotation of Saturn and Jupiter on their axes, there are circumstances which would render unlikely the occurrence of trade-winds, such as those we are familiar with In the first place, the enormous distance of Saturn and Jupiter from the sun would tend to diminish the power of the sun to excite any disturbances in the atmosphere of either planet, whether by the difference between his action on different regions of that atmosphere, or by the evaporation of fluids on the planets' surface, and the consequences which might follow that process, as when it takes place on our own earth But setting aside this consideration, on the ground that peculiarities in the atmospheres of these planets may tend to compensate the effect of the sun's distance, there remains the fact that, owing to the enormous dimensions of the two planets, the variations of temperature between places separated by given distances in Saturnian or Jovian latitude, are far less than the corresponding variations for such distances on our own earth Suppose that, at a certain place on the earth, the air is so many degrees warmer than at a place 50 miles further north, as to lead to the occurrence of atmospheric currents of a given degree of force, then places on Jupiter (one due north of the other), having temperatures differing in the same degree would be separated by more than 500 miles It is clear that the change of temperature would thus take place at a rate relatively so small that the resulting atmospheric currents would be relatively very feeble It seems difficult to conceive, under these circumstances, that, in the trade-winds, astronomers have pointed out the true analogies of the causes producing the belts of Jupiter and Saturn It would appear

more likely that processes are at work which result from heat inherent in the masses of these orbs

BENETNASCH (Arabic) The star η in the constellation Ursa Major It is also called *Alkaid*

BENZIDAM A synonym for Aniline, now obsolete See *Aniline*

BENZOIC ACID An organic acid crystallising in colourless transparent laminæ When pure it has no odour, but it ordinarily retains some of the odour from the gum benzoin from which it is prepared Its formula is $C_7H_6C_2$, it fuses at 121° C (250° F), and distils over at 294° C (561° F) It is slightly soluble in water, but much more so in alcohol and ether Benzoic acid unites with bases, forming a well crystallised series of salts called *benzoates*

BENZOL A limpid colourless oily liquid of a pleasant odour, insoluble in water, but miscible with alcohol and ether Specific gravity, 0 85, boiling point, 86° C (187° F) At 0° C (32° F) it freezes to a white mass resembling camphor It is very inflammable, and evolves much smoke on burning Composition C_6H_6 Benzol was first prepared by Faraday by the destructive distillation of benzoate of lime, it is now prepared in enormous quantities from coal-tar naphtha It is the lowest term of a series of homologous bodies, increasing by the addition of CH_2, the next term being toluol, C_7H_8 Benzol forms a large number of substitution products *Nitrobenzol* is formed by the replacement of one equivalent of hydrogen, by one equivalent of NO_2, its formula being $C_6H_5NO_2$ It is a yellowish oily liquid, having an odour of bitter almond oil, and a sweet taste, it boils at 220° C (428° F), reducing agents convert it into aniline.

BERYLLIUM See *Glucinum*

BESSEMER FLAME, SPECTRUM OF THE The intensely brilliant flame which issues from the mouth of the Bessemer converter during the latter stage of the operation has been submitted to spectroscopic examination by Professor Roscoe, Professor Lielegg, and Dr W M Watts Professor Roscoe has detected in the flame the elements sodium, potassium, lithium, iron, carbon, hydrogen, and nitrogen At a certain stage of the "blow" the carbon lines suddenly disappear, and experience has shown that if the blast of air is turned off at this moment the best results will be produced This point, which formerly could only be ascertained doubtfully and after much experience, is now detected with greatest readiness by means of the spectroscope (See *Spectrum*, *Spectrum Analysis*)

BESTIARY (*Bestia*, a beast) A name given in old works on astronomy to the *Zodiac*, q v

BETELGEUX (Arabic) The star α in the constellation Orion It is a noted ruddy star Sir John Herschell discovered that it is variable

BEVELLED WHEELS (French, *biveau*, a slant, Spanish *bayvel*) The use of bevelled wheels is to transform motion round one axle into motion round another axle which is not parallel to it Suppose the central line of the two axes to be continued till they meet, and a line to be drawn through the point of intersection bisecting the angle between the axes Imagine this line to be rigidly connected first with one axis, and then with the other When the axes revolve, two cones, touching one another, will be traced out by the bisecting line If the surfaces of the cones be rough the revolution of one will produce rotation of the other If instead of using the whole surface of the cones we place teeth along circular sections of the two cones, bevelled wheels will be formed The surfaces of the teeth, therefore, form part of the surfaces of cones having the same vertex As an illustration, consider the case where the motion is required to be at right angles to that already produced Since the axes produced would meet at right angles, the bisecting line will be at 45° with each, and consequently the teeth on the bevelled wheels must be inclined at an angle of 45° to the axles, instead of being parallel to them Thus when the first wheel rotates the second will revolve regularly, and produce motion about an axle at right angles to the first Bevelled wheels are much used in machinery and clockwork. They are better adapted than crown wheels for machines performing heavy work (See *Toothed Gear*)

BIAXIAL CRYSTALS, INCLINATION OF OPTIC AXES OF See *Optic Axis of Biaxial Crystals, Inclination of*

BICHROMATE OF POTASH. See *Chromates, Chromate of Potassium*

BIELA'S COMET A comet of short period (see *Comet*), remarkable on account of the near approach of its orbit to the earth's, and to the orbit of *Encke's Comet* (q v), and still more remarkable as having divided into two distinct comets in 1846 In 1852 it was still double In 1859 its return to perihelion was not observed owing to the unfavourable position of the earth In 1866, the epoch of its last calculated return to the sun's neighbourhood, this comet was not discovered by astronomers, who remain unable to explain its apparent disappearance from the solar system

BIFILAR BALANCE. See *Balance, Bifilar.*

BILE, or, *Gall* An animal liquid contained in the gall bladder Specific gravity about 1 02 It is transparent and thick, of a green or brown colour, and of a peculiar odour, it contains a resinous matter, colouring matter, fatty acids, and cholesterin, together with mineral constituents

BINARY STARS See *Stars, Double*, &c

BINOCULAR STEREOSCOPIC MICROSCOPE (*Binus*, two, and *oculus*, an eye) It was not till some time after Sir C Wheatstone's discovery of the stereoscope that the principle of binocular vision was successfully applied to the microscope The first instrument of this kind was made by Nachet of Paris, but his arrangement is now superseded by Wenham's binocular prism, which is almost universally attached to good microscopes Professor Smith has devised a binocular eye piece which enables stereoscopic effects to be obtained with a single body microscope, whilst Wenham's arrangement requires two bodies The advantages of the binocular over the monocular microscope, in addition to the effect of solidity which it confers upon the objects, are, that the penetrating power or focal depth is greatly superior whilst its employment is attended with very much less fatigue to the eyes It must be borne in mind that these advantages are only met with in the stereoscopic binocular, and that instruments which are binocular but not stereoscopic, *i e*, which present to each eye images which are essentially identical, only possess these advantages in a very limited degree (See *Microscope, Stereoscope*)

BINOCULAR VISION The phenomena of binocular vision have been fully examined by Sir Charles Wheatstone It will be evident on a little thought that a solid body near at hand is seen from a slightly different point of view by the right eye than by the left eye If one eye be closed the effect of relief and solidity vanish, and Sir C Wheatstone discovered that the cause of the sensation of solidity was due to the mental union of these two slightly dissimilar images on the retinae The stereoscope is an instrument based upon this fact (See *Stereoscope*)

BISMUTH A metal which was discovered by Agricola in 1529 Its symbol is Bi, and its atomic weight 208 It frequently occurs in the native state or in combination with sulphur, and is extracted by heating the mineral in inclined tubes, whence the metal flows into receptacles The impure metal is separated from sulphur and other impurities by fusion with nitre Bismuth is a pinkish white metal, very brittle, and highly crystalline, some of its artificial crystals are of extreme beauty and considerable size Its specific gravity is 9 83 It melts at 264° C (507° F) and expands in solidifying It is neither ductile nor malleable, but may be readily powdered Exposed to the action of a powerful magnet it is repelled from the poles, being diamagnetic The following are its most important compounds —

Oxides of bismuth The principal oxide is the *trioxide* (Bi_2O_3), which is formed when the metal is heated with free contact of air It is a pale yellow powder The hydrated oxide ($BiHO_2$) is obtained as a white precipitate on adding a caustic alkali to a solution of subnitrate of bismuth This oxide unites with acids, forming the normal salts of bismuth, for a description of which see the acids *Bismuthic acid* (Bi_2O_5) is a bright red powder, forming compounds with alkalies, which have only been imperfectly investigated

Trichloride of bismuth ($BiCl_3$) A white fusible crystalline substance which is decomposed by water with precipitation of oxychloride of bismuth ($BiClO$) This is a pearly white insoluble powder known in the arts under the name of pearl white

Sulphide of bismuth (Bi_2S_3) This occurs native, being known as bismuthine, and it may be prepared artificially by fusing powdered bismuth and sulphur together It is a lead gray crystalline substance, of specific gravity 6 5, somewhat brittle and sectile This compound is also precipitated as a brownish black powder when sulphuretted hydrogen is passed through a solution of a bismuth salt

There are several organic compounds of bismuth

BISSEXTILE (*Bis*, twice, and *sextilis*, sixth) The name given to every year of 366 days The length of the year being a little less than 365¼ days, Julius Cæsar, in reforming the calendar, arranged that in every fourth year February should have 29 days instead of 28, and to avoid inconvenience, two following days of the lengthened month were called by the same name The day thus repeated (so to speak) was the 24th of February, or, according to the Roman nomenclature, *sexto calendas Martii* Hence the year in which this title was given to two successive days received the name *bissextile* (See *Leap Year*)

BLACK LINES OF THE SPECTRUM See *Fraunhofer's Lines*.

BLAST FURNACE See *Iron*

BLAST FURNACE GASES See *Iron*

BLEACHING POWDER See *Chlorine, Hypochlorites*

BLOOD, ABSORPTION LINES IN The colouring matter of blood is capable of existing in two states of oxidation, producing different absorption bands in the spectrum. Red

blood gives two wide somewhat indistinct bands in the red part of the spectrum, whilst deoxidised blood gives only one black band somewhat intermediate in position with the other two Professor Stokes has termed these colouring matters red and purple *cruorine* By the action of an acid on blood, a substance called *hæmatin* is produced, which gives three absorption bands in the red, orange, and green, which are again reduced to two bands by deoxidising agents In cases of poisoning by the inhalation of carbonic oxide, the blood is found to give another characteristic set of bands, (see Professor Stokes' paper, Proc R S 1864, p 355) (See *Absorption of Light, Spectrum, Spectrum Analysis*)

BLOWPIPE An instrument of much use in preliminary chemical examinations It consists essentially of a tube about seven inches long, one end of which is supplied with a mouthpiece, whilst the other is bent at right angles, and terminates in a fine nozzle When a stream of air is blown through it into a gas, oil, or spirit flame, a long narrow dart of flame is produced, which, by adjustment, will present the appearance of a clear blue cone interiorly, and an indistinct colourless outer envelope The inner flame possesses reducing properties, whilst the outer flame is oxidising By heating small portions of mineral substances on platinum wire or charcoal in these flames, either with or without the addition of re agents, much valuable information is afforded as to the constituents of the body under examination Blowpipe analysis has therefore become an important branch of analytical chemistry, and owing to the great portability of all the apparatus, and the ease and rapidity with which results can be obtained, it is invaluable for the travelling chemist and mineralogist

BLOWPIPE, OXYHYDROGEN See *Oxyhydrogen Blowpipe*

BLUE VITRIOL See *Sulphates, Copper*

BODE'S LAW The name given by astronomers to an empirical law by which the distances of the planets seem associated The law was not discovered by Bode, however, having been put forward before his time by Kepler and Titius

The law may be thus exhibited —Under the names of the several planets in the order of their distance set the number 4 Then below this row of fours write in order the numbers 0, 3, 6, 12 24, 48, and so on, the 0 falling under Mercury, the 3 under Venus, and so on Adding the several columns thus obtained, we obtain the following result —

Mer	Ven	Earth	Mars	Ast	Jup	Sat	Uran	Nept
4 0	4 3	4 6	4 12	4 24	4 48	4 96	4 192	4 384
4	7	10	16	28	52	100	196	388

The numbers thus obtained correspond closely with the relative distances of the planets, except only in the case of Neptune The real distances, calling the earth's distance 10, are as follows —

Mer	Ven	Earth	Mars	Ast	Jup	Sat	Uran	Nept
3 9	7 2	10	15	27 5	52	95	192	300

It will be seen that the distance of Neptune falls far short of that which Bode's law would assign to a trans-Uranian planet Under *Asteroids* and *Neptune* will be found a reference to two important services which this empirical law has rendered to astronomy

Similar relations have been detected among the distances of the satellites of Jupiter and Saturn In the case of Jupiter's system, the constant number is 7, the number multiplied is 4, and the constant multiplier 2½ In the case of Saturn's system, the constant number is 4, the number multiplied is 1, and the constant multiplier 2

It has been remarked by Gauss that the series resulting from Bode's law is not a true progression, because, inverting the added numbers, we ought not to have . 12, 6, 3, 0, but 12, 6, 3, 1½, &c This difficulty may be removed by considering the law as applying only to the distances of Venus, the earth, &c, from the orbit of Mercury So considered, these distances successively increase by mere doubling, and the law becomes not only complete, but much simpler

It seems difficult to believe that a law so well marked, and fulfilled so closely in so many instances, is not in reality the result of physical relations of some sort, though it is by no means easy to see what those relations may be

BOHNENBERGER'S ELECTROMETER, or *Electroscope*, as it ought to be called, is a common single gold-leaf electroscope (see *Electroscope*), to which is added a pair of dry piles

placed vertically one on each side of the gold leaf. One of these piles has its positive end uppermost, and the other its negative end They are furnished with large brass knobs, and, by means of a screw at the bottom of the case of the instrument, can be moved parallel to themselves nearer or farther from the gold leaf When the instrument is uncharged, the gold leaf hangs down between the knobs, but in giving it the slightest charge, it is attracted by one of the piles and repelled by the other, and thus moves in a direction which indicates at once the nature of the charge that it has received.

BOILER See *Steam-boiler*

BOILING POINT The boiling point of a liquid is the temperature at which the elastic force of its vapour is equal to the pressure of the air, or other surrounding medium This temperature is dependent upon various causes which are discussed under the heading *Ebullition* The following table of boiling points and densities has been condensed from that given by Dr W A. Miller —

TABLE OF BOILING POINTS OF VARIOUS SUBSTANCES.

NAME OF SUBSTANCE	Boiling Point Fahrenheit	Specific Gravity at 32° F.
Liquid sulphurous acid,	17 6	
Aldehyde,	69 4	0 8009
Ether,	94 8	0 7365
Bisulphide of carbon,	118 5	1 2931
Acetone,	133 3	0 8144
Bromine,	145 4	3 1872
Wood spirit,	149 9	0 8179
Alcohol,	173 1	0 8151
Benzole,	176 8	0 8991
Water,	212 0	1 0000
Butyric ether,	238 8	0 9041
Perchloride of tin,	240 2	2 2671
Terchloride of arsenic,	273 0	2 2050
Bromide of silicon,	308 0	2 8128
Terbromide of phosphorus,	347 5	2 9249
Sulphuric acid,	640 0	1 8540
Mercury,	662 0	13 5960

BOLIDE (βολίς, a missile) See *Meteors, Luminous.*

BOLOGNA FLASK, See *Prince Rupert's Drops*

BOOTES In astronomy (*the Herdsman*), one of Ptolemy's northern constellations It contains the bright star Arcturus, and the singularly beautiful binary star Mirach, or Epsilon Bootes, deservedly named by Admiral Smyth *Pulcherrima*

BORACIC ACID See *Boron*

BORAX See *Boron*

BORING TOOLS Implements used to ascertain the nature of the materials to be excavated previous to the commencement of earthwork They consist of the boring tool proper, which is of wrought iron, steeled at the cutting edges and points, and about 3 feet long, and the lengthening rods, which are square bars, usually about 10 feet long, and terminated by screws, so that they can be connected together, or to the boring-tool proper The uppermost rod can be attached to a long horizontal bar about 6 feet long, driven by two men, and also to a block and tackle by which the rods may be hauled up when required The working part of the tool is of various forms, the *auger* which is used for all ordinary earths and soft rock is a cylinder about 3½ inches in diameter, with an open sharp-edged slit along one side, and slightly contracted at the lower end, which sometimes terminates in a gimlet, the *worm* is a sharp pointed spiral, used for rock too hard for the auger, the latter being used after it to enlarge the bore and bring up the fragments When the rock is very hard, a *jumper* is used—that is, a kind of chisel with a sharp edge, worked by raising it a short distance and letting it drop, turning it a little way round after each blow Boring machines have been lately used extensively for driving headings in tunnelling through hard rock The most remarkable is the boring apparatus used in making the tunnel through Mont Cenis This tunnel is 8 miles long, and had to be excavated entirely from the two ends without the aid of shafts The machinery consists of a number of horizontal jumpers, driven at the rate of about 200 blows per minute by machinery, moved by air compressed by hydraulic machinery near the outer end of the mine, and conveyed into the mine through a pipe By using eight jumpers for six hours, about sixty holes of 3 feet long, and 1¼ inch diameter, are made in the face of the rock, and are used for

blasting with gunpowder By this means a mass of rock was removed in ten hours about 12 feet broad, from 7 to 10 feet high, and 3 feet deep

BORON A non metallic element, which was first obtained in the free state from boracic acid by Gay-Lussac and Thénard in 1808, and immediately afterwards by Sir Humphry Davy In the amorphous state, it is a dark greenish brown powder, opaque, free from taste and smell, and a non-conductor of electricity when un-ignited, it is slightly soluble in water, when heated to about 300° C. (572° F) it burns in the air, forming boracic acid Boron also exists in the graphitoidal form as well-defined six sided crystals, perfectly opaque, and of a semi-metallic lustre An adamantine or diamond boron is also known in the form of quadratic octahedrons, specific gravity 2 63, and sometimes as hard as the diamond, and of a scarcely perceptible honey-yellow colour Boron forms compounds with all the other elements, but the only ones which we can here allude to are boracic acid and the borates

Boracic Acid (in the anhydrous state B_2O_3) is the only known oxide of boron It is a colourless, brittle, glassy mass after fusion, of specific gravity 1 83 It melts at a little below redness It dissolves in water and alcohol Its alcoholic solution burns with a beautiful green flame, (the same colour being produced when a boron compound is heated before the blowpipe), and crystallises from its aqueous solution in white translucent pearly plates, which have a bitterish, cooling taste It is obtained principally from the volcanic district of Tuscany, and more recently from borax lakes in California and other parts of the world Although not acid to test paper, it unites with bases, and forms well defined salts called *Borates* The only one which need be mentioned here is the

Biborate of Soda or Borax ($2NaBO_2 B_2O_3$) It is found native in many parts of the world, and in the crude state is known in commerce as *tincal* In the pure state, ordinary borax contains ten equivalents of water, and forms large transparent prisms, which, when heated, intumesce considerably, forming a bulky white spongy mass, which, at a red heat fuses to a colourless clear glass Borax is readily soluble in water, forming a solution which has a slight alkaline reaction Owing to its easy fusibility and its property of forming readily fusible compounds with other metallic substances, borax is of great use in the arts and manufactures It is also much used as a blowpipe-test owing to its forming transparent glasses of characteristic colours when melted on a platinum wire loop, with small quantities of compounds of copper, chromium, cobalt, iron, manganese, &c

In its chemical characters, boron is similar to silicon. There are many organic compounds of boron

BORONATROCALCITE A native borate of calcium and sodium, met with in South America, and sometimes used as a source of boron compounds Formula, $2(NaCa_2H_3B_6O_{12}) + 15aq$

BORROWING DAYS A name given to the days of cold weather commonly occurring from about the 11th to the 14th of April Before the change of style, these days belonged to the beginning of April, so as to justify the following lines, often heard in North Britain .—

" March borrows frae April
Three days and they are ill
The first o' them is wun' an' weet,
The second it is snaw and sleet ,
The third o' them is a peel a bane
And freezes the wee bird's neb tae stane "

BOYLE'S LAW The law of the relation between the pressure and volume of a gas It states that if the temperature remain the same, the volume of a gas varies inversely as the pressure The experiment by which the law was proved by Boyle and Marriotte, will serve as an illustration Let a bent tube of glass be taken, closed at one end, and let mercury be poured into the open end, thus separating the air in the closed part from the external air When the mercury is just sufficient to separate the air, it stands of course at the same level in both parts of the tube Let us suppose the mercurial barometer to be at 30 inches when the experiment is tried, then the pressure on the air is equivalent to that of 30 inches of mercury Let more mercury be poured into the open tube, the air in the closed part will be compressed, but the levels of the mercury will not be in the same horizontal line. When the mercury stands in the longer arm of the tube at 30 inches above the level of the shorter, the air will be compressed into half its former bulk It is now under a pressure of twice 30 inches of mercury or two atmospheres, and the space occupied is half that when the pressure is one atmosphere If the level of the mercury in the longer arm be twice 30 inches above that in the shorter, so that the whole pressure is three atmospheres, the volume of the compressed air is one-third of the original volume, and so on, the general law being that the space occupied by the air is inversely proportional to the

pressure. The law may be also stated thus the product of the volume and pressure is always the same

BRACHISTOCHRONE (βραχυς, short, βραχιστος, shortest, and χρονος, time) A line joining two points, such that if a particle falling from one of the points be constrained to move along the line, the time of motion to the other point will be shorter than if the particle moved between the points along any other path The problem to find the brachistochrone or curve of quickest descent, for a particle sliding under the action of gravity, from one of two points to the other which is neither in the same horizontal nor vertical line, is very celebrated in the history of Dynamics The curve in this case is a cycloid, that is, the curve traced out by a point on the circumference of a circle which rolls on a straight line

BRAKE (German, *brake*) A piece of mechanism for retarding or stopping motion by friction, or by locking the wheels of carriages by pressure The brakes in machinery connected with stationary engines usually consist of a belt of leather, passed round one or more wheels, and tightened by means of a lever Brakes for carriages are contrivances for stopping, wholly or partially, some or all the wheels, so that they slide instead of roll The maximum effect of a brake is obtained when it completely stops the revolution of the wheels on which it acts In the case of railway carriages the increased resistance produced by the brake brings the train to rest in the course of *a time* directly proportional to the speed, and inversely to the resistance, and of a *distance* directly proportional to the square of the speed, and inversely to the resistance. The distance in the course of which a train is stopped is of more importance practically than the time Ordinary brakes consist of two blocks of wood made to fit two adjacent wheels, and brought in contact with the wheels by a combination of levers, screws, and bevelled wheels They are worked by hand in carriages called ' brake vans" Brakes have been devised to act on all the wheels at once by mechanism worked by steam Such brakes stop a train moving with a speed of 10 miles an hour in 24 feet, of 30 miles an hour in 216 feet, and 50 miles an hour in 600 feet With ordinary brakes these distances are respectively 108 to 144 feet for 10 miles an hour, 972 to 1296 for 30 miles an hour, and 2700 to 3600 for 50 miles an hour Mr Fairbairn's Report to the British Association on Brakes, 1859, may be consulted for further information

BRAMAH'S PRESS See *Hydraulic Press.*

BRANNITE See *Manganese, Oxides*

BREAK, or *Rheotome* A name given to contrivances used in many electric instruments for making and breaking a circuit through which a current flows The form of it depends entirely upon the special purpose for which it is used The very simplest break is a common file If one wire from the battery be put in contact with it and the other be drawn briskly along the surface, the circuit is made and broken as the wire passes from tooth to tooth Again, a toothed wheel turned over the surface of mercury is frequently used, one wire being connected with the mercury and the other with the wheel As the teeth enter and leave the mercury the circuit is made and broken Of self acting breaks there are also many, for example, that of Ruhmkorff's induction machine is a small hammer of soft iron pressed by means of a spring against a little anvil, and the current passes from the one to the other But the hammer is placed between the anvil and the soft iron core of the primary coil, and as soon as the current flows the core becomes a magnet and attracts the hammer to itself, thus breaking the circuit The circuit being broken the core ceases to be a magnet, and the hammer springs back against the anvil again, and the current passes once more Other *breaks* and *commutators* are described in connection with the instruments to which they are applied

BREATH FIGURES If glass, or other smooth surface, be written on with a wooden point, the characters become visible by breathing on the surface Hence such figures are termed *Hauchfiguren* by German writers, and *figures roriques*, or *roric* figures, by the French, (from *ros*, "dew," gen *roris*)

There are various modes of producing such figures *Moser's figures* depend on the proposition that if any two bodies be brought sufficiently near each other, and face to face, one of them impresses its image on the other Thus the glass used to protect a framed print receives an invisible impression of the print, which may be made visible by exposing the glass to vapour of water, iodine, mercury, &c The inscription on the back of the inner case of a watch is repeated on the inner side of the outer case The parts of machines in contact or near together impress themselves on each other, and so on

Breath figures are easily produced by common electricity If a coin be placed on glass, and a stream of sparks be directed upon it during some minutes, on throwing off the coin and breathing on the glass an image of the coin will be produced In such case the film which covers the glass, in common with all bodies exposed to the air, is burnt off in a more or less graduated manner, according as the parts of the coin near the glass are more or less raised

These burnt off portions being more or less chemically clean than the other parts of the glass, condense the breath in various ways as compared with the unburnt portions, from minute globules of dew to continuous sheets or lines of water Hence the image and superscription are made out by the condensed moisture of the breath Some of the figures belonging to the first named class probably depend on some obscure molecular change in the surface of the material, similar to the latent images in plates that have been submitted to photographic action, and apparently well cleaned Such images sometimes start into existence when the plate is again photographically treated For an application of Breath Figures that is calculated to dispel a superstition see *Lightning Figures*

BREGUET'S HELIX See *Metallic Thermometer*

BREWSTER'S THEORY OF THE SPECTRUM As the result of numerous experiments on the decomposition of light by absorption in coloured media, Sir David Brewster was led to the conclusion that the solar spectrum consists of three spectra of equal lengths, viz, a red, a yellow, and a blue spectrum, each having its maximum of intensity in the middle of the space of its own colour in the spectrum, and declining rapidly at each side This view is now generally considered erroneous (See *Brewster's Optics*, chap vii p 71) See *Spectrum*

BRIDGES (A Saxon, *brycg*) Any structure of wood, stone, brick, or iron raised over water, or roads for the passage of men and other animals Among rude nations bridges are sometimes formed of other materials, and sometimes they are made of boats In tracing the history of bridges we find, as might be expected, that they were first used in countries the physical features of which made extensive inland communications impossible without them No bridges are found amongst the remains of ancient Egypt The Greeks paid no attention to bridge architecture until after their conquest by the Romans The Romans understood the importance of building permanent structures over rivers, and were well acquainted with the principles of the arch at an early period Many of these arches have resisted all attacks of time They are chiefly semicircular, some, however, consisting of a smaller segment The importance attached to the care of bridges by the early Romans is shown by the fact that the highest Roman sacerdotal title was that of pontifex (= bridge maker, from *pons* and *facio*) The chief of the pontifices, called the *pontifex maximus*, was always created by the people and chosen from those who had borne the chief offices in the state From this word the title of *pontiff* in modern Europe is derived The earliest Roman arch now standing is the Cloaca Maxima built by the elder Tarquin

One of the earliest bridges over the Tiber was the Pons Sublicius (*sublicæ*, stakes or piles) It was built by Ancus Martius, and dedicated with great pomp and solemnity by the Roman priest It was re built with stones by Æmylius Lepidus, whose name it assumed Some vestiges of it may still be seen Other bridges over the Tiber and Arno were Pons Cestius built in the reign of Tiberius by Cestius Gallus, Pons Aurelianus, built of marble by Antoninus, Pons Janicularis, which is still standing, Pons Fabricius, Gardius, built by Agrippa, and Palatinus, near mount Palatine, also called Senatorius, begun by Fulvius and finished in the censorship of Mummius, portions of which are still standing Trajan's bridge over the Danube, designed by Appolodorus of Damascus, was perhaps the most magnificent structure of the kind in the Roman period It was 4770 feet long, and supported by 20 square piers 150 feet high, 60 feet broad, and 170 feet from each other It was destroyed by Hadrian the successor of Trajan From the Roman period to the Middle Ages few bridges of large dimensions were erected In the twelfth century an order was instituted, termed the Fretes Pontiers, for building bridges, and under their direction a bridge was completed at Avignon in 1176 In 1354, at Verona a bridge was built consisting of three arches, the largest 160 feet span In 1454 one was built over the Allier in France having a span of 184 feet The Rialto, at Venice, was commenced in 1588 It was built by Michael Angelo. It has a span of 98⅛ feet and is 23 feet above the water In 1774 a bridge was completed over the Seine at Neuilly by Perronet, the father of the modern system of art, consisting of five arches, each having a span of 39 mètres (= 128 feet nearly), a rise of 9 75 mètres (= 32 feet nearly) Bridge building in England has more than kept pace with that on the Continent One of the earliest arches built in the last century was a one arch bridge over the Taffe in Glamorganshire, built in 1756 by a country mason, William Edwards It is the segment of a circle whose diameter is 175 feet The span is 140 feet, height 35 feet, and abutments 32 feet

Wooden Bridges Very durable bridges can be constructed of timber, and when it is difficult to procure stone or iron for the purpose, wooden bridges are chosen on the ground of expense The *trusses* of the bridge should be arranged so that pressure is transmitted from one to the others, as is the case with the parts of a stone bridge, so that instead of being weakened by the passage of heavy loads they will become stronger

Temporary and Moveable Bridges. Temporary bridges are frequently made by bracing to-

gether a number of boats, and laying planks over them The bridge built by Darius over the Hellespont or Dardanelles to pass from Asia to Europe was of this kind, and surpassed all modern military bridges Portable floating vessels, termed pontoons, are now used instead of boats, in constructing military bridges The pontoons used in the British army are tin cylinders, with hemispherical ends, and are of two sizes, one being 22 feet 3 inches long, and 2 feet 8 inches in diameter, the other 14 feet 9 inches long, and 1 foot 7 inches in diameter *Draw bridges*, made to take up or let down, as occasion serves, before the gate of a town or castle, were much used in the fortifications of the middle ages It is frequently necessary, in navigable rivers and docks, to make bridges which can be easily moved Such bridges usually cross the water near its level, are made of timber or iron, and are capable of being opened so as to leave the navigation clear and closed, so as to form a passage for a road or railway There are five kinds of movement used with these structures —1 By turning about a horizontal axis. 2 By turning about a vertical axis 3 By rolling horizontally 4 By lifting vertically 5 By floating on the water Besides having the strength and stiffness required in a fixed bridge, a moveable bridge must fulfil some other condition If it turns about on axis, it must be balanced so that its centre of gravity will always lie in the axis, if it rolls, its centre of gravity must always lie over the base or platform on which it rolls

Suspension Bridges These bridges are formed by suspending between two piers a cable or chain, and hanging a platform from it by means of vertical rods

SUSPENSION BRIDGES

Name	River and Place	Widest Arch		Curve	Architect	Date
		Span	Rise			
		Ft In	Ft In			
Menai	Sea over Menai Straits	570 0	42 0	Deflection	Telford	1820
Fribourg	Valley at Fribourg	880 0	63 0	Deflection	Calley	1830
La Roche Bernard	Vilaine at La Roche Bernard	650 4	50 0	Deflection	Leblanc	1846
Pesth	Danube at Pesth	666 0	45 0	Deflection	T Clarke	1850
Niagara	St Lawrence at Niagara	821 4	75 0	Deflection	Roebling	1848

Iron Bridges The first iron bridge erected in England was that built over the Severn, near Coalbrookdale in Shropshire, by Abraham Darley, in 1780, consisting of one arch of 100 feet span In the next year another iron bridge was built over the same river at Buildwas, and a third, having a span of 236 feet, and a height of 60 feet above the water, was built at Wearmouth in Durham

IRON BRIDGES (CAST)

Name	River and Place.	Widest Arch		Curve	Architect	Date
		Span	Rise			
		Ft In	Ft In			
Southwark	Thames at London	240 0	24 0	Segment	Rennie	1818
Sunderland	Wear at Sunderland	240 0	30 0	Segment	Wilson	1796
Buildwas	Severn at Buildwas	150 0	27 0	Segment	Telford	1816
Tarascon	Rhone at Tarascon	204 4	16 6	Segment	Unknown	1859
Westminster	Thames at London	120 0	13 0	Elliptical	Page	1861
Blackfriars	Thames at London	200 0	15 0	Segment	Cubitt	1870

IRON BRIDGES (WROUGHT)

Name	River and Place	Widest Arch		Curve	Architect	Date
		Span	Rise			
		Ft In	Ft In			
Britannia	Sea over Menai Straits	458 3	19 3½	Tubular	Stephenson	1850
Saltash	Hamoaze at Plymouth	433 6	30 6	Tubular	Brunel	1860
Victoria	St Lawrence at Canada	330 0	31 8	Tubular	Stephenson	1858
Cologne	Rhine at Cologne	313 0	31 0	Lattice	Unknown	1862

Two species of iron bridges have been used to secure flat ways for railroads Bridges of the first kind are supported by iron braced girders, which are either *Warren* girders (formed like the letter W repeated horizontally), *lattice* girders, or *bowstring* girders. Examples of these are

furnished by the railway bridges over the Thames at Charing Cross, Blackfriars, and Cannon Street Bridges of the second kind are supported by tubular girders, and are therefore termed tubular bridges The girders are hollow, and so large as to allow the traffic of the bridge to pass in the interior They are composed of iron plates riveted together, forming at the top and bottom of the girder rows of square cells The three largest bridges of this description are the Britannia Bridge over the Menai Straits, the Conway Railway Bridge, and the Victoria Bridge over the St Lawrence

Authorities on Bridges —Gauthey, Traité de la Construction des Ponts, Annales des Ponts et Chaussées Weale's Bridges Smiles's Lives of the Engineers Rankine, Applied Mechanics. Fairbairn, On Tubular Bridges Clark, On the Britannia and Conway Bridges Hodges, On the Victoria Bridge Stephenson, On Iron Bridges in the Encyc Brit

BRIDGE, WHEATSTONE'S, is an arrangement for comparing the electric resistance of wires There are several forms of apparatus for the purpose The following description will illustrate the principle of all —Imagine four thick pieces of brass, each provided with three binding screws, and placed, insulated from each other, at the angles of a square. Let them be called

A, B, C, and D Thus
$$\begin{array}{ccc} & A & \\ D & & B \\ & C & \end{array}$$
Let then four resistances be inserted, two of them, which are known, between A and D, and A and B, and two, which are to be compared, between D and C, and B and C Let the terminals of a battery be attached to B and D, and the terminals of a galvanometer be attached to A and C Now the current will divide (see *Current, Divided*) at B and D, and flow in the two circuits B A D and B C D, and there will besides be the wire passing round the galvanometer, in which a current might flow from A to C, or from C to A, if there were any electromotive force in either direction, and such a current would be indicated by the galvanometer But it can be shown that there will be no such an electromotive force unless a certain ratio exist between the resistances B A, A D, D C, C B, unless in fact the proportion

$$BA : AD :: BC : CD$$

holds, and that if this proportion holds there will be no current Now, if either B A or A D, the known resistances, is alterable, we can put in resistance, or take it out, till there is no deflection of the galvanometer By this means we readily determine the ratio of B C : C D Lastly, if one of these be known in proper units, the other likewise becomes known

BRITISH ASSOCIATION UNIT The unit of electric resistance determined on by the Committee appointed by the British Association for the Advancement of Science, to examine into the question of the units of electric resistance. (See *Resistance, Units of Electric*)

BRITISH GUM See *Dextrin*

BRITTLENESS (Anglo Saxon, *bryttan*, to break) The property of easily breaking It is generally possessed by hard and elastic substances, which only permit very slight displacement of their particles without breaking It is a property not marked out by definite limit, but is the opposite of flexibility, so that bodies which are less brittle are more flexible, and conversely, as bodies become more brittle, they are less flexible Steel, after being heated red-hot, and suddenly cooled, becomes very brittle and hard, but if very slowly cooled, it is comparatively soft and flexible Glass, though very elastic, is one of the most brittle substances known (See *Flexibility, Hardness, Elasticity*)

BROMAL A substance produced by the action of bromine on alcohol Formula, C_2HBr_3O It is analogous to chloral, and is a transparent, colourless oil of specific gravity, 3 34 It possesses a peculiar pungent odour, and like chloral it forms a hydrate containing two atoms of water, and crystallises readily

BROMINE (βρῶμος, an offensive odour) A non metallic element belonging to the chlorine group It is a liquid of a deep red brown colour, very volatile, and of a peculiar irritating, repulsive odour Specific gravity 2 966 It solidifies at −22 (−7 6° F), forming a hard brittle mass of a lead-gray semi metallic appearance Boiling point, 58° C (136° F) Symbol Br Atomic weight, 80 It is slightly soluble in water, more so in alcohol, and miscible with ether in all proportions Its chemical energies are very powerful, it unites with all elementary bodies, forming, for the most part, well marked compounds or *bromides* Bromine closely resembles chlorine in its properties, being the second term of the chlorine, bromine, and iodine group Bromine forms several oxygen compounds, the most important of which is *Bromic Acid* ($HBrO_3$), which unites with bases forming *bromates* The principal compound of bromine is the hydrogen compound, or hydrobromic acid

Hydrobromic Acid (H Br), is a colourless gas, having a very pungent odour It is eagerly absorbed by water, forming a strongly acid solution which fumes in the air On exposure to air it decomposes slightly, oxygen being absorbed and bromine separated. Hydro-

bromic acid perfectly saturates bases, forming metallic bromides, which will be described under their respective headings

BROOKITE See *Titanium Di-oxide*

BRORSEN'S COMET See *Comets*

BUBBLES The term bubble is applied to a great variety of different conditions of liquids in relation to gases We shall confine ourselves here to the consideration of the size of bubbles of gas formed in the midst of a liquid medium For further details the reader is referred to a paper by the author of this article, Proceedings R Soc, xiv, p 22 The size of the bubbles are measured by measuring the volume of water which flows out of an aspirator, which draws a gas in the shape of a certain number of bubbles through a liquid The rate at which the bubbles are formed has little or no influence on the bubble size The nature of the gas has also little or no effect, the bubbles formed under like conditions of nitrogen, air, carbonic acid, oxygen, and hydrogen, being sensibly the same The size of the bubble is also inappreciably altered by change in the ordinary atmospheric temperature and pressure With regard to the size of the orifice out of which the bubbles issue, it is found that the bubble size may be doubled by increasing the diameter of the tube five times But this relation varies with the actual size of the orifice The chemical nature of the liquid is of great influence on the bubble size In our series of experiments, the bubble size of air through several media was the following — Mercury, 41 2, glycerine, 11 45, water, 8 60, alcohol, 4 80, turpentol, 4 53, &c

BUNSEN'S GALVANIC BATTERY In this battery the cells consist of an outer vessel filled with dilute sulphuric acid, in which is placed a zinc plate, and within this is a porous cell containing strong nitric acid, and having a prism of carbon immersed in it It is seen thus that the battery is a modification of Grove's nitric acid battery The invention of Bunsen consisted in making the carbon prism, which he produces by pressing together into an iron mould a mixture of coke dust and powdered coal, and then heating it in a furnace A mass is thus obtained, which, after soaking in gas tar, possesses high conducting power Instead of these prisms it is usual now to employ prisms cut from the hard carbon which collects in the roofs of gas retorts. The chemical reaction which takes place in the Bunsen cell is the same as that in the Grove cell, the nascent hydrogen being got rid of by the decomposition of the nitric acid, and the polarization of the conducting or carbon plate due to its presence being thus avoided The Bunsen battery possesses the great advantage of cheapness over that of Grove.

BUNSEN'S PHOTOMETER consists essentially of a screen of fine writing paper, the transparency of the central portion of which has been increased by being saturated with melted spermaceti On one side, at a distance of a few feet, is placed the standard light, usually a sperm candle of a particular make, and on the other side the light whose relative intensity is to be ascertained The two lights are attached to graduated bars, and their distances from the screen altered until the spots of grease on the paper ceases to be visible when viewed from either side. The intensities of the two lights will then be to one another as the squares of their distance from the screen (See *Photometry*)

BUOYANCY When a body is immersed in a fluid (liquid or gas) and exhibits a tendency to rise, it is said to be buoyant For the cause and measure of buoyancy see *Displacement of Liquids* and *Specific Gravity*

BURNING LENS By concentrating the sun's rays by means of a convex lens of short focus in comparison to its diameter, the heat becomes enormously intensified With the lens constructed by Mr Parker, a sheaf of rays 3 feet in diameter, was concentrated into a focus of half an inch, at this point platinum, gold, copper, quartz, flint, topaz, garnet, asbestos, &c, were melted in a few seconds A lens for burning purposes need not be achromatic, nor constructed with that extreme precision necessary in the case of astronomical lenses. (See *Lens*)

BURNING MIRROR See *Concave Mirror*

BUTTER OF ANTIMONY See *Antimony*.

C

CABLE, CAPACITY OF By the capacity of a submarine cable is understood the property which it possesses of accumulating electricity just as does a Leyden jar If one end of a cable be "cut," that is, disconnected from the earth, and in fact insulated, and if one pole of a battery be applied to the other end, the second battery pole being put to earth, a current is found to flow from the battery into the cable, and may be observed by means of a galvanometer placed between the battery and the cable Again if by means of a commutator the battery be cut off from the cable, and the cable at the same moment put to earth, a current will be found to flow out of the cable, showing that it was charged The fact is that a submerged cable acts precisely as a Leyden jar, the conducting wire of the cable takes the place of one coating, the

water that of the other, while the insulating material performs the office of the glass or other non-conductor

The inductive effect here referred to is of very great importance with respect to the working of submarine cables To it is due the phenomenon known by the name of *inductive embarrassment* (which see), which causes both delay and the peculiar slow exit from the cable of the signal (See also *Electricity, Velocity of*)

CABLE, SUBMARINE, is the whole compound rope used in submarine telegraphy It consists essentially of the conducting wire through which the signal is sent, and of the insulating coating which prevents electrical communication between the wire and the water or bottom on which it lies, and around the insulator there is always an exterior coating of some kind to prevent the destruction of the insulator both during the submersion and after it We shall briefly describe the construction of a cable Within the last few years much experience, often dearly bought, has been gained in making them, but the most important that have been lately submerged, namely the three which join America with England and France, and those which connect India with England have been thoroughly successful, and the pattern on which they are made is now very generally adopted.

The conductor is made of copper wire of the very best quality. The choosing of the wire is a matter of the highest importance, for, as Sir W Thomson pointed out in 1858, very great differences are to be found in conducting powers of various specimens of copper wire, differences which may make the rate of telegraphing 40 per cent faster or slower according as a better or worse wire is taken Matthiessen showed that pure copper wire is superior to all alloys, and construction companies now reject copper whose conductivity is not 95 compared with pure copper taken as 100 The conductor consists of several wires twisted together so as to form a rope Formerly one wire was used, but a number of wires twisted together is found much preferable, as one or two of them may be broken without any damage being done to the cable, whereas a single thick wire parting, as it frequently does at a brittle place, completely interrupts the communication In small cables three wires are twisted together to form a rope, in a large one seven are used In the Atlantic cables the gauge of the strand thus formed is 0 144 of an inch

The insulator consists of gutta percha and Chatterton's compound, which is a mixture of pitch and resinous matter The wires are first covered with Chatterton's compound, and the interstices between them filled up with it, and by this means the passage of water along the strand is prevented, should any reach it by accident The strand is then passed through a vat containing melted gutta percha, and is drawn through a die of a proper size so as to lay on a coating of the required thickness After this three layers of Chatterton's compound and three more of gutta percha, are applied alternately in a similar manner The gauge of the *core*, as it is called, after the insulating covering was applied, was, in the case of the Atlantic cable, 0 454 of an inch The covering the wire by means of several successive coatings is of great importance, for it is almost impossible to put on a single coating of sufficient thickness so that the wire shall be in the middle of it, and there is great danger in doing so, of leaving air bubbles within it, which, being penetrated by the water, permit the copper wire to be exposed to it

In order to protect the core thus formed from injury it is now overlaid with wet tanned hemp, and over this serving of hemp, iron wires are laid spirally along the cable The hemp protects the core from injury by the iron wires, and the iron wires give the strength to the cable, which is necessary during the paying out of it from a ship, and which prevents its being cut and destroyed by rocks and unevennesses of the ocean bed The iron wires are galvanised to protect them from rust, and in some cases are separately covered with a serving of hemp

Under *Atlantic Telegraph* some particulars with regard to the most important existing cables will be found

CACODYL See *Arsenic*

CADET'S FUMING LIQUID See *Arsenic*

CADMIUM A metallic element associated in nature with zinc, discovered independently by Stromeyer and Hermann, Atomic weight, 56, Symbol, Cd Cadmium is a soft white metal with a slight bluish colour It is susceptible of a high polish, but tarnishes after a short time It is highly crystalline, and when bent, crackles like tin It is very malleable and ductile, fuses below redness, and volatilises below the boiling point of mercury Cadmium is readily soluble in dilute acids, and forms well defined salts In chemical characteristics cadmium strongly resembles zinc, and is obtained in commerce as a by-product in the manufacture of this metal The principal compounds are the following —

Protoxide of Cadmium Cd_2O anhydrous, and CdHO in the hydrated state The former is a brownish yellow powder, formed when cadmium is ignited in the air The latter is a white precipitate, obtained by adding an alkali to a solution of a cadmium salt.

F

Bromide of Cadmium (CdBr) A beautiful pearly crystalline compound, formed by the direct union of cadmium and bromine

Chloride of Cadmium (CdCl) A transparent micaceous crystalline body, formed when a solution of cadmium in hydrochloric acid is evaporated and crystallised, in this condition it contains one equivalent of water, which is evolved at a higher temperature

Iodide of Cadmium (CdI) This is easily prepared by the direct union of the two elements under water or alcohol It forms large transparent six sided crystals which melt easily, and at a high temperature sublime, with partial decomposition The three latter salts are much used in photography, on account of their solubility in alcohol

Sulphide of Cadmium (Cd_2S), occurs native as the mineral Greenockite, and is prepared artificially by passing sulphuretted hydrogen through a solution of a cadmium salt It is an orange yellow powder permanent in the air, and unaffected by atmospheric impurities, hence it is of great value as a pigment, known under the name of *Cadmium Yellow*

CÆLUM In astronomy (abbreviated from *Cœla Sculptoris*, the sculptor's tools), one of Lacaille's southern constellations

CÆSIUM (*Cæsius*, sky blue) An alkaline metal discovered in 1860 by Kirchhoff and Bunsen by means of spectrum analysis, (which see), symbol Cs, atomic weight, 133 In its chemical qualities the compounds of cæsium are closely allied to those of potassium One of the most important characteristics of cæsium is its spectrum reaction, which exhibits two blue lines close together, from the colour of which the name is derived

CAFFEINE, or, *Theine* A white crystalline substance extracted from tea or coffee It separates from its solutions in silky needles, which have a slightly bitter taste, and contain $C_8H_{10}N_4O_2+H_2O$ Caffeine melts at 178° C (352° F) and sublimes without decomposition at a higher temperature It is a weak base, and forms salts with acids

CAIRNGORM See *Quartz*

CALAMINE, SILICIOUS See *Silicates, Silicate of Zinc.*

CALC SPAR See *Iceland Spar*

CALCIUM The metallic basis of lime, first isolated by Davy in 1808 It is a light yellow metal about as hard as gold, very ductile and malleable, and possessing a specific gravity of 1 5778 It rapidly decomposes water, and when heated, burns with a very bright flash, atomic weight, 20, symbol, Ca The most important compounds are the following —

Oxide of Calcium, or *Lime* (Ca_2O) In the anhydrous state this oxide is known as quick lime, and is prepared by heating carbonate of lime (limestone or chalk) in kilns, the mineral being mixed with coal The carbonic acid passes off at a red heat, and lime is left behind Pure lime is a greyish white porous mass of specific gravity, 2 3 to 3 0, is infusible at the highest heat of a furnace, has very great affinity for water When moistened, lime becomes very hot, a great deal of steam is evolved, and the mass soon crumbles to a dry white powder This is called the *slaking of lime* Lime containing many impurities, such as silicates, slakes slowly The resulting compound known as hydrate of lime, or slaked lime, (CaHO), is a soft white powder slightly soluble in water, and crystallising from its aqueous solution in prisms, the whole of the water is driven off at a red heat, the solution is alkaline to test paper Lime is a powerful base, and saturates acids, forming well defined salts Its uses in the arts are very numerous

Chloride of Calcium (CaCl) is formed by neutralising lime with hydrochloric acid, and evaporating to dryness and heating the residue It forms a white porous mass, which attracts water greedily, and is of great use in laboratories for drying liquids and gases It crystallises with three equivalents of water in six sided prisms

Fluoride of Calcium (CaF) This is met with abundantly in nature, as *Fluorspar*, frequently crystallised in large cubes It is transparent, and occurs white, purple, pink, &c, and when in large masses, is of great value for ornamental purposes It also occurs in minute quantities in the teeth and bones of animals It is much used as a flux in metallurgical operations

Phosphide of Calcium A dull brown mass, prepared by passing vapour of phosphorus over red hot lime The formula of the compound is not well ascertained When thrown into water it decomposes with evolution of phosphuretted hydrogen, the bubbles of which take fire spontaneously on coming into contact with air or oxygen gas

CALENDAR (*Calendarium*, from the obsolete verb *calo*, to call) A distribution of time according to years, seasons, months, weeks, &c, according to the usages or wants of civil life

The *year* or period of the sun's apparent revolution around the sidereal heavens is the basis of all modern calendars The *day*, or period of the sun's apparent revolution *with* the sidereal heavens around the earth is the principal subdivision The year is measured with reference to the return of the seasons, the day with reference to the average interval separating successive returns of the sun to the meridian But, in forming a calendar, account has to be taken of the fact that the year does not contain an exact number of days, but 365d. 5h 48m 49 6s.

This would not be the place to enter into a full account of the various processes by which men have gradually made the calendar correspond more and more closely with the actual relations presented by the astronomical year It will be sufficient to refer the reader to the full treatment of the subject by Professor de Morgan in the Companion to the Almanac, 1845, and to Sir J Herschel's account in his Outlines of Astronomy What more immediately concerns us here, is the relation between the calendar at present in use, called the *Gregorian*, and that devised by Julius Cæsar

In the Julian year, as in the more ancient calendars, the month was used as a convenient subdivision, twelve months being included in the year, because the year more nearly contains twelve than any other number of exact lunations The several months contained as many days as according to our modern use Thus the ordinary year contained 365 days Every fourth year contained 366 days (see *Bissextile*), and no further arrangement was made to bring the civil year into accordance with the actual length of the astronomical year Thus four years contained 1461 days, instead of 1460d 23h 15m 0 18s , so that, supposing the Julian year to be exactly accordant with the progress of the seasons at some fixed epoch, the several dates would gradually fall more and more in advance of the seasons, the amount of error being about 44¾ minutes in four years, 1h 29½m in eight years, and so on , or with sufficient approximation we may take error to be three quarters of an hour in four years, and, therefore, one day in about 128 years (more exactly 128 88 years)

It followed that, as century after century passed, the equinoxes and solstices fell gradually away from their true dates, occurring rather more than three days too late in the calendar year at the end of the fourth century, more than six days too late at the end of the eighth century, and so on

It was to correct this state of things that the calendar now in use was devised by Pope Gregory XIII It differed only from the Julian in making all the years divisible by 100, but not by 400, common years It thus provided for the omission of 3 days in each 400 years, as compared with the Julian calendar Now we have seen that in 128 9 Julian years there was 1 day too many, or 3 days too many in 386 7 years , so that the Gregorian calendar only leaves uncorrected in 400 years the amount of error which had before accrued in 13 3 years By a further arrangement, dropping the extra day belonging to the years 4000, 8000, &c —that is, by making these years common years, the Gregorian calendar would further provide for an error equivalent to that arising in 133 Julian years, a correction of 1 day, which would cause an over correction in 4000 years, corresponding to the error which actually accrues in 4 Julian years—that is, corresponding to about three quarters of an hour This improvement we may safely leave to a remote posterity, an arrangement which causes an error of less than a day in 4000 years being sufficiently exact for all the purposes which a calendar is intended to subserve

When the Gregorian calendar was first introduced into Catholic countries in 1582, 10 days had to be dropped All the Protestant countries except England adhered to the old style till the year 1700, when the correction was still effected by a change of 10 days only, the year 1600 being, according to the Gregorian calendar, bissextile But England maintained the old style till 1752, and then the correction involved the omission of 11 days, the day following September 2d being called the 14th, instead of the 3d of that month Russia, and all countries in communion with the Greek Church, still maintain the old style , and should they adopt the new style before 1900, will have to omit twelve days , after 1900, and before 2100, the correction will be 13 days

CALIPPIC PERIOD See *Cycle*

CALMS, REGION OF A belt about 4° or 5° in breadth, extending across the Atlantic and the Pacific, somewhat variable in position, lying in about 25° N lat in July, and travelling thence to about 25° S lat, in January It is generally parallel to the equator The barometric pressure over this region is low

CALOMEL See *Mercury*, *Chlorides*

CALORESCENCE (*Calor*, heat) A term introduced by Professor Tyndall to designate the transmutation of invisible heat rays into rays of higher refrangibility, that is, into visible rays Sir William Herschel discovered the fact that, beyond the red end of the spectrum, there are invisible heat rays of great intensity Suppose a sunbeam is caused to pass through a prism, it is split up into rays of different refrangibility, occurring in the order of violet, indigo, blue, green, yellow, orange, red This experiment constitutes the so called decomposition of white light, and was first made by Newton Sir W Herschel, in passing a delicate thermometer through the various portions of the spectrum, found that the temperature gradually rose as it passed from the violet to the red end, and the red was found to be the hottest portion He then moved his thermometer into darkness beyond the red, and found an indication of a

considerable amount of heat,—in fact, a greater amount than had been found in any part of the visible spectrum. It was thus clearly demonstrated that invisible heat rays accompany the visible light rays emitted from the sun. The relationship of the heat spectrum to the light spectrum has been determined by Sir W. Herschel and Professor Muller in the case of the solar spectrum, and by Professor Tyndall in the case of the spectrum of the electric light. (See *Heat Spectrum*.) The last mentioned physicist, in attempting to sift the luminous from the calorific rays of the total radiation from the voltaic arc, tried various substances with a view of finding something which should cut off the whole of the light, and allow the heat to pass. He ultimately decided on using a solution of iodine in bi-sulphide of carbon. The bi-sulphide alone was found to absorb only 5.2 per cent of the heat rays passing through it; and when iodine was added until the solution was perfectly opaque, the absorption of heat was scarcely increased, while the absorption of light was complete. When a beam of light from the sun, or from the electric lamp, was passed through a layer of this opaque solution, and concentrated by a lens, the dark heat rays were brought to a focus, at which intense calorific effects were manifested; black paper was instantly set on fire, gunpowder and gun cotton were exploded, and thin plates of tin and zinc fused. At the dark invisible focus, carbon was brought to incandescence, and caused to burn vividly; blackened silver leaf was brought to a red heat, copper was melted, and platinized platinum rendered incandescent. It was necessary in these experiments to blacken bright surfaces exposed to the focus of dark heat, otherwise the reflection of heat would have been so considerable that the substance would not have absorbed a sufficient amount to raise it to a red heat. Here, by ultra-red invisible heat rays, Tyndall raised metals to incandescence,—that is, they emitted light of their own—and we perceive at once that this is virtually a transformation of invisible rays into visible rays. The ultra-red rays possess low refrangibility; the vibrations which produce them are long, and move too slowly to produce in us the sensation of vision; they fall as dark invisible heat on the platinum, or other metal raised to incandescence, and they leave it as light; the slow vibrations have become quicker, the long waves have become shorter, the refrangibility has been raised. This change of heat rays into light rays is *calorescence*.

The transmutation is complete. The invisible heat rays are not converted into light of one kind, for when a piece of white hot platinum is examined by means of a prism, a complete spectrum is obtained—in a word, the heat rays of low refrangibility are converted into light rays of all refrangibilities. A detailed account of the experiments in connection with this subject will be found in Tyndall's *Heat Considered as a Mode of Motion*, and in his various memoirs in the *Philosophical Transactions*. (See also *Obscure Heat*, *Heat Spectrum*.)

CALORIC. Heat, regarded as a species of matter, was for a length of time called caloric. Fourcroy, in speaking of the cause of it, says, "Some have considered it merely as the consequence of motion excited among the particles of bodies, while others have attributed it to a self-existent body; and chemists, who study its progress, determine to a certain point its quantity, or at least its proportion in different systems of bodies compared together and even estimate its various attraction; have a thousand means of accumulating the proofs of the second opinion. It is to them that the term *Caloric* owes its origin, which they have adopted to distinguish the body that produces the sensation, from the sensation itself, or the heat excited." This passage occurs in the most extensive work on chemistry which existed at the commencement of this century, and it serves to show how completely at that date the science of heat was associated with chemistry; that, in fact, heat had no separate existence as a distinct science, and that hence, as we have endeavoured to show elsewhere, it is among the youngest of the sciences. (See also *Heat*.)

CALORIE. (*Calor*, heat.) A term used by the French to designate the unit of heat which they adopt. It is the amount of heat necessary to raise 1 kilogramme (2.2046215 lbs avoirdupois) of water one degree centigrade in temperature, strictly from 0° to 1° C. A calorie when converted into mechanical force, is competent to raise a weight of 1 kilogramme to a height of 425 metres (one metre is equal to 3.2808992 feet), and conversely the fall of 1 kilogramme through a space of 425 metres represents, as heat, one calorie. (See *Mechanical Equivalent of Heat*, *Unit of Heat*.)

CALORIFIC CAPACITY. See *Specific Heat*.

CALORIMETER. See *Calorimetry*.

CALORIMETRY. (*Calor*, heat, *μετρέω*, to measure.) In discussing the thermometer and its use, we have mentioned that it indicates relative not absolute amounts of heat; it shows the condition of a body in regard to sensible heat, that is, the temperature of the body, but the real amount of heat absorbed or emitted by a substance cannot be determined by thermometrical means. *Calorimetry* is the branch of the science of heat which treats of the absolute measurement of heat, and the instruments employed for such determinations are called *Calorimeters*.

The existence of two such terms as *Thermometry* and *Calorimetry*, in the same science, is undoubtedly unfortunate, because as far as their derivation is concerned, they might both apply to the same classes of phenomena The thermometer was invented and named before calorimetry had been even thought of, and when the latter came to be practised, it was thought that no term which did not express the measurement of heat, could with any justice be applied to determinations of absolute quantities of heat, and the only convenient term remaining was calorimetry It would be preferable to call the thermometer a *thermoscope*, and the calorimeter a *thermometer*, but it is unlikely that the latter term, from its comparative antiquity, will ever cease to be used in its present form

For the exact measurement of heat some unit is requisite, and by reference to the article entitled *Unit of Heat*, it will be seen that three forms of thermal unit are employed to wit, the amount of heat necessary to raise 1 lb of water from 32° to 33° F , or the amount necessary to raise 1 lb of water from 0° to 1° C , or again, the French unit or *Calorie*, viz , the amount of heat necessary to raise 1 kilogramme of water from 0° to 1° C The absolute quantity of heat absorbed or given out by substances in passing through a given range of temperature compared with that absorbed or given out by water under similar conditions is called its *specific heat* (which see) , we have here to examine the various methods by which specific heat is determined, in other words, the various processes of calorimetry

Three principal methods are employed for the determination of specific heat In the first the heat is measured by the amount of ice which it melts , in the second, known as the *method of mixtures*, bodies of different temperatures are mixed with water, and the heat calculated from that of the mixture , and in the third, or *method of cooling*, the heat is determined by noticing the time which a body requires to cool.

1 *Determination of Specific Heat by Fusion of Ice* —The first and rudest form of calorimeter was a block of ice containing a cavity covered by a lid of ice , a known weight of the substance to be examined, at a known temperature, was placed in the cavity, and when it had cooled down to the temperature of the surrounding ice, it was removed, and the cavity was wiped dry by a weighed cloth, which, on being again weighed, obviously gave the weight of water resulting from the fusion of the ice by the substance introduced This calorimeter was employed by Black and Wilke , it was greatly improved by Lavoisier and Laplace, and used by them for the determination of the specific heat of a number of substances The instrument in its improved form is known as the *Ice Calorimeter*, and consists of three concentric vessels, in the innermost of which the substance whose specific heat is to be determined is placed, the surrounding vessel is filled with ice, and is provided with a tap for drawing off the water, while the outermost vessel also contains ice, and is for the purpose of preventing the melting of ice in the intermediate vessel, by other means than the heat of the warm substance in the central vessel The chief objection to this instrument is, that the actual quantity of water resulting from the fusion of the ice, cannot be accurately determined, because some remains in contact with the unmelted ice

2 *Method of Mixtures* —According to this method, a known weight of the substance whose specific heat is to be determined, is heated to a known temperature, and is then immersed in a known weight of cold water, the precise temperature of which is noted The temperature which results from the immersion of the warm body, when both it and the water possess the same temperature, is then observed, and the specific heat of the immersed substance calculated therefrom

3 *Method of Cooling* —When equal volumes of different substances at the same temperature are allowed to cool under precisely similar conditions, the rate of cooling is found to vary considerably It has been found that equal weights of different bodies cool through the same number of degrees of temperature in times which are directly as their specific heats hence the application of this method to such determinations It has been chiefly employed by Dulong and Petit, and by Regnault (See also *Specific Heat*)

CALOTYPE PROCESS (καλος, beautiful, and τυπος, a representation) The name given by Mr Fox Talbot to the photographic process first discovered by him It consisted essentially in soaking good writing-paper, first in iodide of potassium solution, then, after drying, in a mixture of nitrate of silver solution, acetic acid, and gallic acid, in a dark room, and exposing it to the luminous image in the camera, for a space of time varying from a fraction of a minute to half an hour or more After exposure the paper is again soaked in a solution of nitrate of silver and gallic acid, when the latent image gradually makes its appearance, and is fixed by bromide of potassium or hyposulphite of soda solution This image is called a negative, and has the light and shadow reversed To procure from it a positive, having the light and shade as in nature, it is placed over a sheet of sensitive chloride of silver paper and exposed in a pressure frame to sunshine The paper is then washed and the image fixed with hyposulphite of soda The process, of which the above is an outline, is historically interesting as being the first prac-

ticable photographic process discovered It is, however, now superseded by the collodion process, although for brilliancy of effect and artistic appearance some of the early calotype pictures, especially when of large size, have never been surpassed This is also called the *Talbotype* process (See *Photography*)

CAMELEOPARDALIS (In astronomy, *The Giraffe*) One of the constellations added by Hevelius to the northern star groups It belongs to a region of the heavens in which stars are but sparsely distributed It would be well if the inconvenient name of this constellation were exchanged in favour of *Camelus* (the camel)

CAMERA LUCIDA (Light Chamber) An instrument contrived by Dr Wollaston for taking drawings of landscapes It consists of a peculiarly shaped prism of glass which is fixed close to the eye, a sheet of paper being placed at a distance convenient for drawing upon By double reflection in the prism the image of the landscape is made to appear projected on the paper and its outline may then be traced with a pencil The camera lucida is frequently replaced for microscopic purposes by Soemmering's steel mirror or a neutral glass reflector

CAMERA OBSCURA (Dark Chamber) A convex lens has the property of projecting a reduced image of an object which is in front of it and if precautions are taken to cut off all extraneous light, to have the lens of the most fitting curvatures and focal length, and to receive the image on an appropriate surface, the appearance will be very beautiful The old form of Camera Obscura consisted of a simple convex lens fastened into a hole at one end of a box, whilst a diagonal mirror at the other end reflected the rays upwards upon a sheet of ground glass, at the top of the box, on which the image was viewed by an observer standing above a screen cut off side light from the ground glass The camera obscura is now almost entirely confined to photographic purposes, and the shapes and forms are varied according to the requirements of almost each operator The lenses are corrected so as to bring the visual and chemical rays to the same focus, and are either single or compound, according as portraits or landscapes are principally required to be taken For portraits, a combination of lenses is employed by which a large aperture and short focus is secured, giving a highly luminous image but not covering a large field, whilst for landscape purposes a single achromatic lens is preferred, and the aperture is somewhat reduced so as to obtain a large flat field with near and distant objects in practically the same focus Rackwork adjustments are used for the lens, and gray glass focussing screens, and in the best instruments this screen, together with the dark slide carrying the sensitive plate are adjusted so as to be inclined at any requisite angle (See *Calotype*, *Photography*)

CAMPHOR A white, waxy, and semi transparent substance, crystallising in octahedra It melts at 175° C (347° F), and boils at 204° C (399° F), although it sublimes to some extent at the ordinary temperature Formula $C_{10}H_{16}O$ It has a strong aromatic odour, is very slightly soluble in water, but very soluble in alcohol, ether and oil, and it burns easily in the air, evolving much smoke

CAMPHOR, MOTIONS OF, ON WATER When some fragments of camphor are thrown on the surface of clean water, contained in a chemically clean glass, they become endowed with lively motions of rotation and progression If, while thus in motion, the water be touched with the finger or with a speck of oil or greasy matter, the motions are immediately arrested These phenomena have excited a large amount of attention on the part of scientific men during nearly two centuries, and the various theories on the subject are described by Mr Tomlinson, in a volume published in 1863, in Weale's Series, under the title of Experimental Essays (See also *Philosophical Magazine* for December 1869) These phenomena have only recently received a satisfactory explanation, an account of which is given under *Surface Tension*

CANCER (In astronomy, the *Crab*) A sign of the Zodiac The sun enters this sign on or about the 21st June, and leaves it on or about the 22d of July The first point of the sign marks the summer solstice, and the declination parallel through this point is called the Tropic of Cancer The constellation Cancer now occupies the place corresponding to the sign Leo Within this constellation is the interesting star-group, called the Præsepe, or the Bee hive, on either side of which lie the two stars called Aselli, the visibility or invisibility of which was regarded by the ancients a a weather portent

CANES VENATICI (In astronomy, the *Hunting Dogs*) One of the northern constellations invented by Hevelius Within the limits of this constellation are several very remarkable nebulæ

CANICULAR DAYS; or, *Dog Days* A name given to the forty days of the year between July 3 and August 11. The name is derived from the Latin name of the dog star Sirius This star rose heliacally about the beginning of July, (see *Heliacal*), and the

ancients ascribed the great heat of summer to the influence of this star At present Sirius rises heliacally at a different season

CANICULAR YEAR. The Egyptian year has been so called because it was determined by the heliacal rising of the dog-star

CANIS MAJOR (In astronomy, the *Greater Dog*) One of Ptolemy's southern constellations This constellation includes the star Sirius, the brightest of all the fixed stars

CANIS MINOR (In astronomy, the *Lesser Dog*) One of Ptolemy's southern constellations The bright star Procyon belongs to this constellation

CANOPUS (Egyptian) The star α in the constellation Argo It is the brightest star in the heavens, with the exception of Sirius only

CANTHARIDIN The active principle of cantharides (Spanish Fly, *Lytta vesicatoria*), also contained in Chinese cantharides (*Mylabris Cichorii*) In the pure state it forms colourless right angled four sided prisms which melt at 200° C (392° F), and volatilise below that temperature, evolving white vapours, which are intensely irritating to the eyes and throat It is insoluble in water, but dissolves readily in alcohol and chloroform Formula $C_5H_{12}O_2$ It has the vesicating power of the Spanish fly in a very high degree

CAOUTCHOUC, or, *India Rubber* A highly elastic substance, obtained from the milky sap of the *Siphonia Elastica* and other arboraceous plants It is colourless and almost transparent in the pure state, but as ordinarily met with it varies from yellowish brown to black At the common temperature it is soft and flexible, but at the freezing point of water it becomes hard and unyielding, between 120° C and 200° C (248° F to 398° F), it melts to a viscid mass which does not dry Caoutchouc is a non conductor of electricity, it is insoluble in water, but soluble in ether, benzol, and bisulphide of carbon When heated with sulphur to about 112° C (234° F), it is converted into what is called *Vulcanised India Rubber*, which has the valuable property of remaining flexible at temperature between 0° C and 50° C (32° F and 122° F) When caoutchouc is heated with half its weight of sulphur, to between 100° and 150° C (212° and 302° F), it becomes converted into a hard black mass, of the consistency of ivory, known as ebonite The composition of caoutchouc is not definitely known, it is, however, a hydrocarbon

CAPACITY FOR HEAT See *Specific Heat*

CAPACITY, SPECIFIC INDUCTIVE A term applied by Faraday to indicate a difference in the powers or capacities which various dielectrics possess for transmitting statical inductive influence across them When a charged body is brought near to an uncharged body, induction takes place that is to say, the uncharged body becomes temporarily excited If it be a conductor, and insulated, electricity of the kind opposite to that with which the first body is charged, appears on the side near to it, and electricity of the same kind on the remote side (See *Induction, Electrostatic*)

According to Faraday's discovery, the amount of this excitement depends upon the material between the plates, or the *dielectric*, as it is called Numbers expressing this difference with reference to some common standard are called the *specific inductive capacities* of the substances In order to examine the specific inductive capacity of various dielectrics, Faraday used what was practically a Leyden jar, the insulating portion of which was capable of being changed He constructed a hollow metallic sphere, having a hole or short neck at the top Through the hole passed a thin metallic rod, carrying a metal ball, which projected into the inner space, and was insulated from the neck of the metal sphere by a plug of shell-lac The outer end of the metal rod was furnished with a small knob He was able to fill the interior cavity of the apparatus with the material which he wished to examine Having prepared two such jars, similar in every respect, and containing in the interspace the substances he wished to examine, he charged one, measured the charge, and then connected the outer knobs of the two together If, then, the inductive capacity was the same for both materials, the charge divided itself equally between them, but if not, that apparatus whose dielectric possessed the greater specific inductive capacity obtained the greater portion of the electricity, and just in that proportion Thus, one being filled with air and the other with shell lac, on connecting the two knobs together and then examining the distribution of the charge, the latter was found to have twice as much electricity as the former The specific inductive capacity of shell lac is therefore 2, if that of air be called unity The following numbers represent the specific inductive capacities of various substances, air being taken as unity —

Air,	.	1 00	Wax,	.	1 86
Spermaceti,	.	1 45	Glass,	.	1 90
Resin,	.	1 76	Shell lac,	.	2 00
Pitch,	.	1 80	Sulphur,	.	2 24

The specific inductive capacity of all gases is the same

According to Faraday's theory induction takes place by means of the polarisation of the particles of the dielectric between the two conductors Those dielectrics, whose particles are most completely polarised, possess the highest specific inductive capacity

Faraday's Experimental Researches, series xi xii xiii xiv (published in 1837 and 1838 in the Transactions of the Royal Society, and republished in a separate form) may be consulted on this subject. Also an instructive paper by Sir W Thomson (in the Cambridge and Dublin Math Journal, 1845, also republished) on the mathematical theory

CAPELLA (The young goat or kid.) The star α in the constellation Auriga It is one of the brightest stars in the northern heavens

CAPILLARITY (*Capillus*, a hair) When a very wide glass tube, open at both ends, is plunged into water, the water is raised up the sides of the glass according to the law given in "Adhesion between Liquids and Solids" This takes place both on the inside and outside of the tube If the tube be very narrow the entire level of the water inside is found to be higher than that outside This difference is greater the narrower the tube If we plunge such a narrow tube into mercury instead of water, a similar difference of level is observed. But in this case the mercury in the tube is depressed below the general level In short, when 2 A is greater than C (see Adhesion between Liquids and Solids), that is, whenever the liquid wets the solid there is a rise of the liquid in the tube, whenever the reverse is the case there is a depression On taking tubes of uniform and various diameters it is found experimentally that the height to which the liquid rises is inversely proportional to the diameter of the tube or to the square root of its sectional area The same law holds good when the liquid does not wet the tube, and when accordingly there is a depression of the liquid in the tube The force which produces these phenomena is called the capillary force or capillarity, and the tubes in which it is exhibited are capillary tubes

It appears also from experiments that the height to which a liquid rises in a capillary tube which it wets, is, under the same conditions of temperature, directly proportional to the specific gravity of the liquid, so that the heavier liquid rises the higher Phenomena of capillarity also takes place in innumerable instances in substances having irregular small cavities, such in fact as are porous In such a solid the liquid which wets it will rise higher according to the smallness of the pores. Thus it will rise higher in a mass of chalk than in one of sandstone. The rise of liquids by capillarity is of great importance in the animal and vegetable world The long cells of which woody fibre is mainly formed are of sufficient minuteness to affect the distribution of sap through great distances, and when through evaporation or solidification a portion of the liquid is removed its place is quickly supplied by capillary action

In the analysis of gases the effect of capillarity is of some considerable importance Such analyses, or the measurements attending them, are usually performed in glass tubes called "Eudiometers," the liquid used being mercury These tubes are generally so wide that the depression of the inner surface of mercury (in reckoning the volume of the gas above the mercury) due to capillarity is negligible But, especially when small quantities of gas are under examination, the depression around the edge of the interior mercurial column is a sensible fraction of the entire volume above So that if the tube be calibrated (its contents volumetrically determined according to a scale of length) according to the volumes above horizontal planes, the volume derived from the reading of the central height of the mercury's surface will be too small The curved surface of the mercury is called the "meniscus" The error so incurred will, in fact, be double the error due to the meniscus if the tube be calibrated in the ordinary way by inverting it and forming a table by reading the height formed by the centre of the meniscus when successive known volumes of mercury are added, for, during the latter operation, a meniscus is formed in the opposite way in regard to the tube The difference of reading when the surface of the mercury is flat, and when it has a meniscus may be once for all ascertained by wetting the surface of the mercury with a drop or two of corrosive sublimate, whereupon the meniscus disappears The author of this article prefers to calibrate the eudiometer by introducing into it successive equal volumes of air when it is in its normal position, whereby the meniscal error being constant, the observed reading corresponds with the actual volume

If a capillary tube, open at both ends, held in a vertical position, be plunged into a liquid which wets it, the liquid will rise in the tube to a certain height above the level of the surrounding liquid If such a tube be removed, and more liquid be added from above, the liquid will bulge out at the lower, and as the column of supported liquid becomes longer until it assumes a hemispherical form, at this stage the height of the included column is exactly twice that of the column supported when the lower end is immersed Further addition of liquid from above causes this hemisphere to burst, and then to fall off in the form of a drop.

When two plates of glass are joined at one edge so as to form a very acute angle and plunged into water with the common edge vertical, it is clear that the space near the angle is narrower than that further away. Such a wedge of space may be regarded as a series of capillary vertical tubes of increasing diameter. The water will accordingly rise highest nearest the corner. The curve which the water forms may be shown both by calculation and experiment to be a right angled hyperbola, the asymptotes of which are the common vertical edge of the glass, and the line at right angles to this bisecting the angle between the glass plates.

The height of the capillary column for different liquids has been the subject of careful experiments, especially by Frankenheim, the result of whose experiments, from Miller's Chemistry, vol. i. p. 71, 4th edit., is given below. The experiments were made at 32° F., or 0° C., in a tube of one millimetre (about $\frac{1}{25}$ inch) in diameter. The height of the capillary column is found to be inversely as the diameter of the tube, but is of course diminished by heat.

CAPILLARY ELEVATION OF LIQUIDS IN GLASS, AT 32° F.

Liquid used	Specific gravity at 32° F	Height in millimetres of the capillary column	Height of the column in thousandth of an inch
Water,	1 002	15 336	604
Acetic acid,	1 052	8 510	355
Sulphuric Acid,	1 840	8 400	331
Oil of Lemons,	0 838	7 23	285
Oil of Turpentine,	0 890	6 76	266
Alcohol (dilute),	0 927	6 41	242
Alcohol,	0 820	6 05	238
Ether,	0 737	5 40	213
Carbonic Disulphide,	1 290	5 10	201

CAPILLARITY, CORRECTION FOR. See *Barometer*.

CAPRICORNUS. (The *Sea Goat*.) A sign of the Zodiac. The sun enters this sign about the 21st of December, and leaves it about the 20th of January. Its first point marks the position of the winter solstice, and the declination parallel through this point is called the tropic of Capricorn. The constellation Capricornus corresponds in position with the Zodiacal sign Aquarius.

CAPSTAN. (French, *cabestan*, Latin, *capistrum*, a halter. So capstan is a machine round which a rope is wound like a halter.) An application of the wheel and axle, used chiefly in ships and ports. It consists of an axle or vertical axis, and a number of horizontal levers. The principle on which its usefulness depends is the same as that of the windlass. If the force applied to each lever be multiplied by the length of the lever, then by the number of levers, and lastly divided by the radius of the axle, the quotient is equal to the weight, when the object is to support it only, and exceeds the weight when the object is to raise or move it. The levers can usually be taken out at pleasure, thus greatly diminishing the compass of the machine when not in use. (See *Wheel and Axle*, *Windlass*.)

CARBAZOTIC ACID. See *Picric Acid*.

CARBOLIC ACID. A compound obtained from coal tar by a somewhat complicated process, also prepared by the destructive distillation of salicylic acid. When pure it crystallises in long colourless needles having a specific gravity of 1 065. It liquifies at 34° C. (93 2° F.) and boils at 187° C. (369° F.) The crystals liquify when in contact with water, and dissolve in about twenty five times their bulk of water, and in all proportions of alcohol, ether, glycerine, and glacial acetic acid. Neither by itself nor in aqueous solution does it redden litmus paper. When pure it has a peculiar pleasant odour, it attacks the skin, reddening and hardening it, it coagulates albumen, and unites with animal substances, it is one of the most powerful antiseptics known, and in a somewhat impure form is largely used for sanitary purposes. The liquid commercial carbolic acid is a mixture of carbolic acid, cresylic acid, various neutral hydro-carbons, &c., its offensive odour is mainly due to the presence of minute quantities of sulphur compounds. (See Runge, Pog. Ann. xxxi. page 69, xxxii. page 308. Laurent, Ann. Ch. Phys. (3) iii. page 195. Williamson and Scrugham, Chem. Soc. J. vii. page 232. Gladstone, Chem. News, ii. p. 98.) Its composition is C_6H_6O. Dr. Calvert (Chem. Soc. J. xviii. page 66) has described a *Hydrate of carbolic acid* of the composition $2C_6H_6O.H_2O$, which crystallises in large six sided prisms, and melts at 16° C. (61° F.) Carbolic acid unites with the stronger bases, but it does not form well defined compounds, and altogether it appears to belong more to the alcohol than to the acid class of bodies.

CARBON. A very abundant non-metallic element, occurring in three forms, crystallised and transparent as the *diamond* (which see), crystalline and opaque as *graphite* or plumbago, and

opaque and amorphous as *charcoal* In the pure state carbon is solid, infusible, and non-volatile. Atomic weight 12 Symbol C In the form of diamond the specific gravity is 3 55, and it is the hardest substance known In the form of graphite, the specific gravity is 1 2, and the hardness is between 1 and 2 of Mohr's scale It conducts electricity nearly as well as metals, it has a metallic, steel gray colour, produces a black shining streak on paper, and is largely used in the manufacture of pencils and crucibles Carbon is a necessary constituent of all organic or organised compounds, and in the form of *charcoal* is prepared by driving off the volatile constituents from wood by heat The carbon prepared in a similar manner from coal is called *coke* A hard and compact form of carbon which has the lustre and electric conductivity of a metal, collects in the upper part of gas retorts This is used as the negative element in Bunsen's voltaic battery Carbon is deposited in the form of soot or lamp black by the imperfect combustion of highly carbonised bodies, such as pitch *Animal Charcoal* is obtained by calcining bones in closed vessels, it consists of a mixture of charcoal and bone ash This form of carbon, owing to its affinity for colouring matter, is used in commerce for removing colour from solutions of sugar and other organic liquids The physical properties of carbon vary with its state of aggregation. Wood and animal charcoal possess a valuable property of absorbing gases, condensible vapours, and colouring matters (See *Gases, Absorption of*) It also possesses the property of inducing the combustion of hydrogen and other gases by means of the oxygen which it condenses from the atmosphere, resembling in this respect spongy platinum At the ordinary temperature carbon scarcely shows any chemical affinity, but at a high temperature it unites with oxygen, with incandescence and great evolution of light and heat, forming carbonic acid, or when the carbon is in excess, carbonic oxide

Carbonic Acid, Dioxide of Carbon, or *Carbonic Anhydride* ($C O_2$), is a colourless gas which may be liquified by a pressure of thirty six atmospheres at 0° C (32° F), and solidified by a still greater reduction of temperature In the gaseous state, its specific gravity is 1 52, owing to which it may with care be poured from one vessel to another like water It is a normal constituent of the atmosphere (see *Atmosphere, Composition of*) It is a non-supporter of ordinary combustion, although potassium and some other bodies will burn in it with separation of carbon or carbonic oxide It will not support life, and in an impure state is the *choke damp* of miners Water dissolves about its own bulk at the ordinary temperature, vegetation decomposes it with separation of free oxygen It possesses acid properties, and unites with bases to form salts The alkaline carbonates are soluble in water, the others are mostly insoluble Carbonates are decomposed by almost every acid with evolution of gaseous carbonic acid. Caustic alkalies rapidly absorb it The following are the most important carbonates —

Carbonates of Ammonium There are several combinations of ammonia and carbonic acid They are all crystalline, volatile either with or without decomposition, soluble in water, and possessing an ammoniacal odour

Carbonate of Barium ($Ba_2O\ C O_2$) in the native state is known as *witherite*, a hard, white, crystalline mineral of specific gravity 4 3 In the artificial state it is a soft, white, insoluble powder

Carbonate of Calcium ($Ca_2O\ C O_2$) This occurs abundantly in nature as limestone, chalk, calc spar, and marble It is also a principal constituent of egg and mollusc shells It crystallises as calc spar in the hexagonal system, and as arragonite in the trimetric system Artificially prepared it is a white powder, insoluble in water, but tolerably soluble in water containing excess of carbonic acid At a red heat carbonate of calcium is converted into caustic lime.

Carbonate of Lead ($Pb_2O\ C O_2$) The hydrated carbonate containing variable amounts of water is prepared by the absorption of carbonic acid by metallic lead in the presence of oxygen and acetic acid It is extensively used in commerce as white lead Some varieties of white lead contain, in addition, oxide of lead, others chloride of lead (See *Lead*)

Carbonate of Magnesium ($Mg_2O\ C O_2$), occurs native as magnesite, and also in the hydrated form, as a white amorphous substance, insoluble in water The hydrated carbonate containing variable amounts of water and carbonic acid, is met with in commerce under the name of *magnesia alba*, and is a very light, bulky, insoluble powder

Carbonate of Potassium ($K_2O\ C O_2$), known also as *pearl ash*, crystallises in the hydrated state in rhombic octahedra, which are very soluble in water When heated it becomes anhydrous, and at a red heat fuses The solution has a strong alkaline taste, when saturated with carbonic acid, it is converted into *bi-carbonate of potassium* ($K_2O\ H_2O\ 2 CO_2$), which crystallises in rhomboidal prisms, much less soluble than the neutral carbonate

Carbonate of Sodium ($Na_2O\ C O_2$), is manufactured in commerce in enormous quantities, and is ordinarily known as soda (See *Sodium*) In the pure crystallised state it forms diagonal prisms containing ten atoms of water, which effloresce in dry air In the anhydrous state it is a white powder, fusing at a moderate red heat. Both the crystals and the anhydrous

salt dissolve readily in water, and form a highly alkaline solution When carbonic acid is passed over the neutral carbonate, or through its solution, *bi carbonate of sodium* is formed ($Na_2O\ H_2O\ 2CO_2$) This has usually the form of a white crystalline powder, which has a slight alkaline taste, and is much less soluble in water than the neutral carbonate

Carbonic Oxide (C O), is a colourless gas of specific gravity 0 96, perfectly neutral, insoluble in water, and very poisonous when inhaled It does not support combustion, but when ignited in the air burns with a lambent blue flame, producing carbonic acid. At a high temperature it acts as a strong reducing agent

Di-sulphide of Carbon (CS_2), is formed by the direct combination of sulphur and carbon at a red heat, it is colourless, strongly refracting, very volatile liquid, having a disagreeable odour, it boils at 46 5° C (116° F), is insoluble in water, but miscible in all proportions with alcohol, ether, and oils Its solvent properties for sulphur, phosphorus, iodine, and many gum resins are very great It is very inflammable, the vapour igniting at a temperature much below redness, it burns with a pale blue flame, producing carbonic acid and sulphurous acid

Tetrachloride of Carbon Carbon forms several compounds with chlorine, of these we need only here mention the tetrachloride (CCl_4) This is a thin transparent liquid, insoluble in water, of specific gravity 1 56, boiling point 77° C (170 5° F) It has a strong aromatic odour, and has been successfully used as an anæsthetic The compounds of carbon and hydrogen are very numerous, those of most importance will be described under their special names Carbon enters into the composition of all organic bodies, indeed, organic chemistry has been defined by Hofmann as a "history of the migrations of carbon"

CARBON, SPECTRUM OF It has been found that every element gives a characteristic spectrum when its vapour is heated to incandescence, but in the case of bodies like carbon, which are non volatile by themselves, their spectra can only be ascertained by comparing *inter se*, the spectra given by its volatile compounds with other elements Mr Swan, Dr Attfield, Dr W M Watts, Mr Huggins, and others, have examined the spectra given by different carbon compounds, and have shown that, although they all give spectra, differing somewhat among themselves, there is yet a certain family relationship throughout, and by ascertaining by experiment on other compounds, the modification which the elements united to the carbon occasion, it has been possible to arrive at a pretty good idea of what the spectrum of carbon is like The general character seems to be that of groups of fine lines in the yellow, green, blue, and violet, each group having its strongest member on the less refrangible end, and fading gradually away toward the more refrangible end It is probable that many of the differences between the various spectra of carbon compounds are due to the different temperature at which they are produced (See *Spectrum*)

CARNOT'S FUNCTION A relation between the amount of heat which leaves a given source, and the work done by it The chief deductions from Carnot's Function are—(1) that the ratio of the heat drawn from the source to the work produced is the same at the same temperature, whatever be the substances composing the machine, (2) that the ratio always depends on the temperature only, and does not vary with the nature of the substance, (3) that a perfect machine is only able to convert into mechanical effect a certain proportion of the heat which leaves its source, this quantity varies directly as the difference of the temperature of the source and refrigerator, and inversely as the temperature of the source The quantity of work produced by a perfect engine in a given time is found by multiplying the quantity of heat which leaves the source in the given time, first, by the difference of the temperatures of the source and refrigerator, then by the number by which the unit of heat must be multiplied, in order to give the mechanical equivalent, and, lastly, dividing by the temperature of the source (See *Thermodynamics*, *Heat Engine*, and *Mechanical Equivalent of Heat*)

CARTESIAN DIVER An instrument, usually in the form of a toy, which admirably illustrates several of the properties of fluids It consists essentially of a glass tube closed at one end, nearly filled with water, and inverted into an cylindrical vessel nearly full of water, the mouth of which is closed air-tight by a membrane of caoutchouc The bubble of air in the internal tube is of such a size that the tube just floats, forming in fact a little floating diving-bell If the membrane closing the outer cylinder be pressed downwards, the pressure is communicated through the air, above the water in the cylinder, to the water By the latter it is conveyed in all directions (see *Pressure through Liquids*) amongst the rest, up through the open end of the inner tube, and up to the bubble of air at the top The latter is compressed The loss in volume suffered by the air is compensated for by the entrance of water The result of this substitution is, that the tube with its contents becomes heavier Being pressed upwards by the same force as before, it is now pressed downwards by a greater one Equilibrium can no longer subsist, and the diver sinks On relieving the pressure, the opposite conditions succeed one another in the inverse order, and the diver rises. Attempts have been made to utilise such

a diver for the purpose of determining, or at least indicating, the barometric pressure But variation in temperature affects the density of the water and the air to such a slight degree, especially the latter, as to invalidate conclusions as to atmospheric pressure drawn from the position of the diver

CARTESIAN SYSTEM The system by which Descartes endeavoured to account for the planetary motions, by the existence of *vorticose* movements in a fluid which he supposed to occupy all space Strange as it may seem, this theory seemed for a long time likely to prevent the reception of the Newtonian astronomy among continental mathematicians The contest between the two systems, however unequal, was pursued with considerable spirit for many years Nor was this unfortunate, since we may ascribe to the struggle the rapid progress of continental mathematicians in mastering the modern modes of mathematical analysis Until comparatively recent times, English mathematicians lagged far behind their continental brethren in this respect

CASCADE, CHARGE BY If several Leyden jars be arranged on insulating supports, and connected in series, so that the inside coating of the second is joined to the outside coating of the first, the inside of the third to the outside of the second, and so on, then if the inside coating of the first be connected with the prime conductor of the electric machine and the outside of the last to the earth, on turning the machine the whole series will be charged The positive electricity driven by induction from the outside coating of the first jar charges the inside of the second, that driven from the outside of the second charges the inside of the third, and so on, and, finally, the positive electricity driven from the outside of the last jar is neutralised by the connection with the earth This method of charging a series of jars at the same time is called *charging by cascade*

CASEIN (*Caseus*, cheese) An organic substance occurring in milk in the soluble form, having great similarity to albumen, it is coagulated by heat and acids, and is the principle constituent of cheese

CASSEGRAINIAN TELESCOPE (So called from the inventor Cassegrain) In this form of reflecting telescope a small convex speculum is placed in front of the large speculum, the rays of light from the object falling on the principal speculum are converged and reflected back to the small speculum, this receives them, and again reflects them to the centre of the large speculum, where a hole is cut to allow them to pass through to the eyepiece One of the largest, and probably the most perfect reflecting telescope in the world is of this construction (See Dr T R Robinson and Mr T Grubb's Description of the Great Melbourne Telescope, Phil Trans, 1869, p 127) (See *Telescope*, *Reflecting Telescope*, *Speculum*)

CASSIOPEIA One of Ptolemy's northern constellations, figured in the maps as a lady sitting in a chair The five principal stars of this constellation form a well known group lying on the Milky Way between Cepheus and Perseus The constellation contains several interesting objects Alpha Cassiopeiae is a well-known variable

CASSITERITE See *Tin*

CAST IRON See *Iron*

CASTOR The star α of the constellation Gemini It is a fine second magnitude binary, the components nearly equal

CASTOR OIL A viscid yellowish oil extracted from the seeds of *Ricinus communis* It has a faint taste and odour Specific gravity 0 97 Chemically it appears to be a mixture of glycerin and several fatty acids

CATACAUSTIC (κατακαυσις, scorching) See *Caustic*

CATALYSIS (καταλυειν, to resolve) A name given to a very obscure class of phenomena, of which little is known, it means action by contact, or chemical action taking place in the presence of a substance which appears perfectly inert and unaffected by anything present As examples, we may mention the conversion of starch into sugar in contact with warm dilute acids, the conversion of cane into grape sugar under similar circumstances, the phenomena of fermentation, the action of finely divided metals in decomposing per-oxide of hydrogen, and the effect of spongy platinum in inducing the combination of oxygen and hydrogen Several explanations have been attempted, but they are all more or less obscure, and fail to meet the majority of instances in which this action is observed

CATHARISM (καθαρος, pure, clean) A term introduced by Mr Tomlinson, with reference to the rendering of nuclei chemically clean (See *Nucleus*)

CATHARIZATION (καθαριζω, to purge, purify, or clean), is the art of clearing the surface of bodies from alien matter, and the substance is said to be *catharized* when the surface is so cleaned

As every thing exposed to the air, or to the touch, takes more or less a deposit or film of

foreign matter, substances are classed as *catharized* or *uncatharized*, according as they have been or not so freed from foreign matter.

The term *catharized*, denoting the condition of pure surface, may also be applied to surfaces that have not undergone the process of catharization. Thus a flint stone, in the rough, has an uncatharized surface; but, when split, the inner surface of the pieces will, for a time, be chemically clean, or in a catharized state.

CATENARY (*Catenarius*, pertaining to a chain; from *catena*, a chain). The curve formed by a uniform flexible string, or chain, suspended from its extremities. The chief properties of the catenary are as follow:—1. Let a horizontal line be drawn at a distance below the lowest point of the string, equal to the length of string, having a weight equivalent to the tension at the lowest point. The tension at any point is the weight of a portion equal to the distance of the point above the horizontal line. 2. The radius of curvature, at any point, is equal to the portion of the normal, intercepted by the curve and the horizontal line. 3. The horizontal tension, at any point, is constant. 4. Of all curves of a given length, drawn between two fixed points in a horizontal line, the common catenary is that which has its centre of gravity furthest from the line joining the points.

If the string vary in diameter, so that the area of a section, at any point, is proportional to the tension at that point, the curve in which the string hangs is called the *Catenary of Equal Strength*. For the theory and properties of the catenary, see Poisson's Mechanics, Ware's Tracts on Vaults and Bridges, Whewell's Analytical Statics, and Wallace in the Edin. Trans., vol. xiv.

CATOPTRICS (κατοπτρικος—κατοπτρον, a mirror; κατα, down; οπσομαι, future of ὁραω, to see). That branch of the science of geometrical optics which treat of the phenomena of incident and reflected light.

CAUSTIC CURVE (καυστικος, καιω, καυσω, to burn). When rays of light are incident upon a curved, reflecting, or refracting surface, the reflected or refracted rays intersect, forming a curved line, to which the rays are tangents. When formed by reflection, this curve is called *catacaustic*, and, when formed by refraction, *diacaustic*.

CAVENDISH EXPERIMENT. An experiment for the purpose of determining the mean density of the earth, investigated by Cavendish, Reach, and Baily. (See *Earth, Density of the*.)

CEBALRAI (Arabic). The star β of the constellation Ophiuchus.

CELLULOSE, (known also as *lignin* or *woody fibre*, $C_6H_{10}O_5$), is an insoluble carbohydrate in an almost pure state; it forms the principal bulk of unsized paper, cotton, or linen; and, in an impure condition, the chief bulk of wood. It is insoluble in water, alcohol, &c.; but, when acted on by strong nitric acid, is converted into nitro-substitution compounds. (See *Gun Cotton*.)

CENTAURUS (The Centaur). One of Ptolemy's southern constellations. Only the head and shoulders of this figure rise above the horizon of London. The constellation, as figured by the ancients, was one of the finest in the heavens, but modern astronomers have taken four of the leading brilliants, and several smaller stars, to form the constellation Crux Australis. The star Alpha Centauri is remarkable, not only as the finest double star in the heavens, and for the great extent of its annual proper motion, but as the star which lies nearest to the solar system, so far as is yet known. The change of the earth's place, during her orbital motion around the sun, produces a parallactic displacement of nearly one second of arc in this star, a fact first detected by Professor Henderson, under circumstances which rendered the observation one of unusual difficulty. Maclear, with superior instrumental means, has confirmed the estimate of Professor Henderson. The actual distance of the star is thus shown to be about 20,000 billions of miles. Near the star Beta Centauri the Milky Way is sub divided, the whole of the galaxy between Centaurus and Ophiuchus being singularly complicated.

CENTRAL FORCES. Forces tending to cause the body, or bodies, on which they act to pass towards, or from, a fixed point, termed the centre of force. If a body starting from rest be acted on continually, by a force tending to a fixed point, the body will, of course, move with constantly increasing velocity up to the fixed point; but if the body be first projected with an initial velocity, in a direction which does not pass through the fixed point, the velocity of the body will not constantly increase, nor will the body be drawn to the centre of force. It is proved, mathematically, that a particle acted on by a central force, when once set in motion in any direction which does not pass through the centre of force, continues its motion in one place, and its path forms a curve.

The straight line drawn from any position of the moving particle to the centre of force is termed the radius vector. One of the most important laws of central forces is that of the conservation of the areas described by the radius vector, proved by Newton as follows:—

When a body is projected with a given velocity, it will pass through a certain space in a straight line, provided no other force be acting upon it. As soon, however, as a central force is made to act upon it, it will be drawn out of the straight line. If, then, we

are able to ascertain the velocity with which the body would move towards the centre, under the action of the central force only, we can determine the position of the body, at the end of a single unit of time, by the Parallelogram of Velocities At the commencement of the second unit of time, we may suppose the body to be again subjected to the impulse of the central force By again compounding the velocity with which the body would now move without the action of the central force, and the velocity due to the central force alone, we obtain the position of the body at the end of the second unit of time It is easily demonstrable, geometrically, that all the triangles formed by joining the successive position of the body, at the end of each unit of time, are equal in area If we now consider the case when the unit of time is indefinitely diminished in duration, and the number of units indefinitely increased, we see that the triangles formed by the motion during each unit are still equal to one another, and the path of the body, instead of being a polygon, becomes a curve, since the polygon, having an indefinitely large number of sides, is identical with a curve The equality of the triangles, referred to above, is therefore expressed, by saying that the radii vectores of the curve sweep out equal areas in equal times, and, consequently, in different times the areas swept out by the radii vectores are proportional to the times. The converse of this is equally true, namely, that if a body moves in a plane curve, so that the radius vector drawn to a fixed point, sweeps out areas proportional to the times, it is acted on by a central force tending to that point

Having obtained these fundamental principles, we arrive at the following results by mathematical reasoning (1) The velocity of a body acted on by a central force, at any point in its path, is inversely proportional to the perpendicular, from the fixed point on the tangent to the curve at the point considered Consequently, if the velocity be uniform, the perpendicular on the the tangent must remain constantly of the same length but since there is but one curve—namely the circle, in which the perpendiculars from a given point on the tangent are all equal, the path of the body must be a circle, and the fixed point must be at its centre (2) If a body describe an ellipse under the action of a force tending to a focus of the ellipse, the intensity of the force is inversely proportional to the square of the distance The same applies to a hyperbolic and a parabolic path (3) If the path be an ellipse, and the centre of force be the centre of the ellipse, the intensity of the force is directly proportional to the distance

The converses of these propositions are also true If a body be projected from a point in a given direction with given velocity, and move under the action of a central force, whose intensity varies inversely as the square of the distance, the orbit is either a hyperbola, a parabola, or an ellipse according to the relation between the velocity and distance of projection

If a body be in motion under the action of a central force, whose intensity varies directly as the distance, the orbit is an ellipse, and the centre of force is the centre of the ellipse In this case the period of revolution is independent of the dimensions of the ellipse, and depends solely on the intensity of the force

On reference to Kepler's Laws obtained by laborious calculations from an immense series of observations, it will be seen that they exactly correspond with the general conclusions respecting central forces, and that consequently the planets describe their orbits under the influence of a central force tending to the sun, and varying in intensity inversely as the square of the distance, and that the force would be the same for each planet at the same distance (see *Kepler's Laws*) We need only suppose the planets to be once set in motion, and then we have quite sufficient to account for their continuous motion and elliptical orbits in the central force tending to the sun We find the planets in motion, there is no force known to us which maintains that motion, and there is no necessity for us to suppose the existence of any other force than that which acts constantly towards the sun

CENTRE, EQUATION OF See *Equation of Centre.*

CENTRE OF GRAVITY That point in a body through which passes the resultant of the weights of the particles composing the body in every position in which the body may be placed The attraction of the earth, which causes a body to have the property called weight, acts upon every particle of the body When a stone is crushed into small fragments, the sum of the weights of the particles is equal to that of the whole stone If one of these particles be attached by a fine thread to a fixed point, the thread will take the vertical direction If several of the particles be suspended from points near together, the threads will be parallel Hence, when the particles are united, so as to form one body, we may consider their weights to be a system of parallel forces, and consequently equivalent to a single resultant By suspending the body from any point, we can ascertain the direction through which this resultant passes If we then suspend the body from another point, we obtain a second resultant, the direction of which intersects the former direction For though the weight and magnitude of the particles are unchanged, each of them will have the direction of its force changed with regard to the whole

body, and the effect is the same as if each force had been caused to turn about its point of application. If the body were of such material that it could be pierced in the direction of the line of support in different positions, all the lines would be found to intersect in a single point, which is called the centre of gravity of the body, or the centre of the parallel forces due to gravity acting upon it. This general fact is stated in the following form:—The resultant of a system of parallel forces acting on a rigid body passes through a fixed point, the position of which is independent of the direction of the forces. If the forces be the weights of the particles, the fixed point is termed the centre of gravity.

The process of finding the centre of gravity of a body may be either experimental or geometrical. When the body is homogeneous, that is, when equal volumes taken from different parts of the body have the same weights, the weights of different portions are proportional to the volumes; thus, in finding the centre of gravity geometrically, we may consider the volumes as forces. A similar process may be taken with very thin sheets, as of metal, paper, &c., of uniform thickness, for since the weights of these are proportional to the areas we may treat the areas as forces, and find the centre of gravity of the surface. Similarly, we may find the centre of gravity of a heavy line, since, in any uniform wire, the weight is proportional to the length.

The following are some of the simpler results of investigation respecting the centre of gravity:—(1.) If a body be symmetrical about a plane, every particle on one side corresponds to a particle equal to it on the other. Hence the centre of gravity of every pair of particles lies in the plane, and consequently the centre of gravity of the entire body lies in the plane of symmetry. (2.) If a body have two planes about which it is symmetrical, the centre of gravity lies in the line of intersection of the planes; and if it have three planes of symmetry, the centre of gravity lies in the point where the three planes intersect. (3.) If an area be symmetrical about a line, the centre of gravity lies in that line. (4.) If a body have a centre of figure—that is, a point such that all lines drawn through it to the outline of the figure are bisected in the point, the centre of figure is the centre of gravity. Hence the centre of gravity of a straight line is its middle point; that of the circumference or area of a circle is the centre; the centre of gravity of a parallelogram is the point of intersection of the diagonals which is the centre of figure; the centre of gravity of a sphere is its centre; that of a right circular cylinder is the middle point of the axis; and that of a parallelopiped is the point of intersection of any two diagonals. In all the above cases, the centre of gravity is the same whether we consider the perimeter and outer surfaces only, or the areas and volumes of the bodies.

From the preceding principles the centre of gravity of the following figures are determined by geometrical rules:—

1. *Of a triangle.* The point of intersection of two middle lines, or that point in the line joining the middle of the base with the opposite angle, which is one third of its length from the base.

2. *Of a semicircle.* At a distance from the base found by dividing two-thirds of the square of the diameter by the circumference.

3. *Of a semi-ellipse.* Same as a semicircle of the same height.

4. *Of a parabola.* Three fifths of the height.

5. *Of a cycloid.* Seven twelfths of the height.

6. *Of a sector of a circle.* At a distance from the centre found by multiplying two thirds of the radius by the chord, and dividing by the arc.

7. *Of a quadrant.* At the same distance from either radius as that of the semicircle.

8. *Of the surface of a hemisphere.* At the middle point of the height.

9. *Of a prism or cylinder.* The middle point of the line joining the centres of gravity of the two ends.

10. *Of a pyramid or cone.* That point in the line joining the centre of gravity of the base with the apex, which is one fourth of its length from the base.

11. *Of a hemisphere.* At three-eighths of the radius.

The following are the chief properties of the centre of gravity. When a body is suspended from a point, it comports itself as if its entire weight were concentrated at the centre of gravity. Consequently, we may consider any body as acted upon by two forces, the resultant of the forces due to gravity, acting at its centre of gravity, and the resultant of the reactions of the points of support. In order that the body may be at rest, these two must act in the same vertical line in opposite directions; if not, the body will move. Thus it results that if the centre of gravity be supported, the whole body will be supported. If the body be suspended from a point, the centre of gravity and the point of support must be in the same vertical line. When the body is supported on several points the condition of rest is that the resultant of all the resistances shall be in the same vertical line with the centre of gravity. It is obvious that this resultant will of

necessity fall within the lines of its component forces Consequently, if the centre of gravity of a body fall without the base on which it stands, it cannot remain at rest, and motion will ensue until the necessary conditions are attained The variations in the position of the centre of gravity in connection with the equilibrium of the forces acting on the body will be treated under *equilibrium.*

CENTRE OF INERTIA. Centre of mass See *Centre of Gravity.*

CENTRE OF GYRATION. See *Gyration, Centre of*

CENTRE OF OSCILLATION See *Oscillation, Centre of*

CENTRE OF PERCUSSION When a solid body is revolving about an axis the point at which a resistance sufficiently strong would stop the rotation of the body without imparting motion to the axis

CENTRE OF PRESSURE (LATERAL) OF LIQUIDS Since (see *Lateral Pressure of Liquids*) the outward pressure on any point of the side of a vessel containing liquid varies with the depth of the point, the pressure at any depth may be represented by the straight line drawn parallel to the base of an isosceles right angled triangle, one of whose sides is the height from the bottom of the vessel to the liquid surface, and the other a horizontal line equal to this drawn from the base Consequently the entire pressure on a line of such points, reaching vertically from the liquid's surface to the bottom, is represented by the area of the above triangle The centre of pressure of such a line of points is that point at which a single pressure will support the whole line of points, supposing the line to be rigid This point is manifestly the point of intersection between the vertical line of points and the horizontal, drawn through the centre of gravity of the above mentioned triangle In other words, it is one-third from the bottom If, therefore, a vessel have a rectangular side the centre of pressure of each vertical strip of the side will be one third from the bottom, or the line of pressure will be a horizontal line at the same depth Finally, the centre of pressure will clearly be the centre of such a line, since the surface is distributed symmetrically around this point

CENTRIFUGAL FORCE (*Centrum*, and *fugo*, to fly from) When a body describes a circle with uniform velocity, there must be a force constantly acting upon it and directed towards the centre If left to itself at any point the body would move in the direction of the tangent at that point, and the force towards the centre is spent at each instant in deflecting the body out of the straight line in which it is moving The force with which the body tends to fly from the centre is termed the *centrifugal force*, and the force which counteracts the centrifugal force is termed *centripetal* These forces are equal and opposite, and each is found by multiplying the mass of the body by the normal acceleration, or, which is the same thing, multiplying the weight of the body by the square of the velocity, and dividing by the acceleration of gravity and the radius of the circle In illustration of this rule let us suppose a stone 1 pound in weight to be tied to a string 3 feet long and whirled round so that its velocity is 24 feet per second, what will be the strain on the string Here, $24 \times 24 \times 1$ lb $-$ $(32 \times 3) = 6$ lbs If the string be not strong enough to bear a weight of 6 pounds it will be broken by the revolution of the one pound The force tending to break the string is the centrifugal force, and that tending to prevent the body from flying off is the centripetal force

CENTRIPETAL FORCE (*Centrum*, and *peto*, to seek) See *Centrifugal Force*

CEPHEUS One of Ptolemy's northern constellations Few of the stars composing this constellation are very noteworthy, and perhaps the most remarkable feature of the asterism is the outlying branch of the Milky Way, extending towards the pole from the star Epsilon Cephei

CERES In astronomy, one of the minor planets. See *Asteroids*

CERIUM A somewhat rare metal, discovered simultaneously by Klaproth and Hisinger, and Berzelius It is almost invariably found associated in nature with the metals lanthanum and didymium, and for many years after its discovery the so called cerium compounds were in reality mixtures of cerium, lanthanum, and didymium Symbol Ce Atomic weight 46 The metal cerium is almost unknown in the separate state, its separation from the two companion metals is difficult, but from other metallic compounds it is easily effected Cerium forms two oxides, a *cerous* or *protoxide* which is unstable, and the *ceroso ceric oxide*, Ce_3O_4 The latter is formed when oxalate or cerium is ignited in an open vessel, and is a yellowish white powder, which becomes orange when heated but gets lighter again on cooling The most definite salts of cerium are those of the protoxide, they are colourless, have a peculiar sweet taste, and are acid to test paper The only salt of present interest is the *oxalate*, which is a white crystalline powder insoluble in water, produced by adding oxalate of ammonia or oxalic acid to a soluble cerous salt This salt is used in medicine

CETUS (The *Whale*) One of Ptolemy's southern constellations. It is figured in ancient charts as an uncouth sea-monster, between whose paws the river Eridanus passes. Within the

limits of this constellation lies the remarkable variable star Omicron Ceti, justly named Mira (See *Stars, Variable*) The constellation is of great extent, and over the larger portion nebulæ are scattered with singular profusion.

CHALCEDONY. See *Quartz*.

CHAMÆLEON (The *Chamæleon*) A southern constellation formed by Bayer. It lies not far from the south pole, and contains few conspicuous stars

CHAPH (Arabic) The star β of the constellation Cassiopeia.

CHARGE, ELECTRIC A body electrically excited is said to be *charged*, and the quantity of electricity which it possesses is the amount of its *charge* There are various ways of producing this state of excitement or *charge*, which are described in the proper places thus we have charge by *conduction* and charge by *induction*, and we have the charging of an insulator by friction, and in other ways, but charge, whenever it is produced, consists in the exhibition of a forced or polarised state on and about the body charged Thus "when a Leyden jar is *charged*, the particles of the glass are forced into this polarised or strained condition by the electricity of the charging apparatus Discharge is the return of these particles to their natural state from their state of tension, whenever the two electric forces are allowed to be disposed of in some other direction" (Faraday, *Exp Researches*, ser xi)

CHARGE, FREE A not very appropriate term used to denote that part of the charge of a Leyden jar or other condenser which acts inductively towards external objects When a Leyden jar is charged, there are two forces which are described as positive and negative electricity in the two coatings If the jar be uninsulated, there is no force on the outside coating *acting towards external objects* We may handle it or examine it with the proof plane, or with a sensitive electroscope, without obtaining any indication of the existence of electric force Induction is taking place through the glass of the jar towards the electricity inside, and in no other direction On the inside coating, on the other hand, a portion of the electricity is acting inductively through the glass towards the outside coating, but there is besides a certain display of force towards external objects. Hence we are able to obtain a charge on applying the proof plane to the ball of the Leyden Jar The portion of the charge which is thus discoverable is called the *free charge*, in contradistinction to the other portion, which is said to be *dissimulated*. If now the jar be insulated, and the interior be touched, the free portion of the electricity on the inside coating is removed A portion of that on the outside now becomes *free*—that is, begins to manifest itself towards external objects, and can be detected by means of the proof plane. Faraday very strongly objects to the use of the term *free charge* (*Exp Researches*, ser xiv), remarking that there is no difference in the mode of action of the *free charge* and of the *dissimulated electricity*

CHARGE, RESIDUAL When a Leyden jar or battery has been discharged and allowed to stand for a few moments, it is found that it still contains electricity This is termed the *residual charge*, or the *electric residue* If it be discharged again, a second residue feebler than the first may be observed after a short time, and, with an electroscope, a third and fourth may frequently be detected The amount of the residue depends upon the intensity of the initial charge, and on the length of time that the jar remained charged The residue charge is due to what is termed *electric penetration* The electricity with which the jar is charged, exerting upon itself a powerful repulsion, appears by degrees to penetrate into the body of an insulating medium such as glass When sufficient time is allowed, a considerable amount may thus be forced inwards On discharging the jar, the influence under which this effect was produced is removed, and the electricity gradually finds its way out of the glass again The phenomenon has been examined in the following way —A plate of the insulating matter is furnished with very closely fitting metallic coatings, which can be removed It is charged and left for a certain time, then discharged, and the coatings removed On examining it by means of the proof plane and electroscope, it is found that, at the first moment after the discharge, there is no electricity on the surface of the insulator, but that by degrees it appears, each side being electrified with the same electricity which its coating possessed Faraday, who studied the question, found that the residue was greatest in the case of paraffin, then came shell-lac, glass, and sulphur, in that order

CHATTERTON'S COMPOUND A resinous and pitchy mixture used in making the insulator of submarine cables. It is laid on in alternate layers with gutta percha. (See *Cable, Submarine*)

CHEMICAL ACTION OF LIGHT Many chemical compounds, especially those of silver, are visibly altered in colour by moderate exposure to diffused day or sunlight It has been found that this action is generally a reduction to the metallic state, or to a lower state of oxidation, and that the rays of light which produce this change are those situated at the most refrangible end of the spectrum (See *Actinism*, *Actinometer*, *Calotype*, *Photography*, *Chemical reactions produced by light*, *Photochemical induction*)

CHEMICAL ACTION OF SPECTRUM See *Actinism*.

CHEMICALLY CLEAN According to Mr Tomlinson, a body is chemically clean, the surface of which is entirely free from any substance foreign to its own composition See *Catharism*, *Nucleus*

CHEMICAL INTENSITY OF DAYLIGHT See *Daylight, Actinic Intensity of.*

CHEMICAL PHOTOMETER See *Actinometer*

CHEMICAL RAYS, ABSOLUTE AND COMPARATIVE MEASUREMENT OF See *Actinometer*.

CHEMICAL REACTIONS PRODUCED BY LIGHT Professor Tyndall has examined the action of an intense beam of the electric light on the attenuated vapours of volatile liquids (*Proc R S*, xvii, p 92) His method of proceeding is as follows —A tube, 2 8 feet long, and 2 5 inches internal diameter, was closed at both ends by glass plates It may be connected with an air pump, and with a series of tubes used for the purification of air A number of test tubes were converted into Wolff's bottles by means of corks and tubes Each test tube was filled partly with the liquid to be examined, and introduced into the path of the purified air When the experimental tube was exhausted, and the air then allowed to bubble through the liquid, a mixture of air and vapour entered the experimental tube together, and was then submitted to the action of light At one end of the experimental tube was placed an electric lamp, transmitting an intense beam of light through the tube parallel to its axis When the vapour of amylic nitrite was allowed to enter the tube in the dark, and the beam of light was then sent through the tube, the tube appeared for an instant optically empty, then a sudden shower of liquid spherules was precipitated on the beam On repeating this experiment with a condensed beam of light, forming a cone 8 inches long, the cone, which was at first invisible, flashed out suddenly, like a luminous spear The rapidity of the condensing action diminished with the density of the light The same effects were produced when oxygen or hydrogen were employed as carriers, when the heat of the beam was sifted out through a plate of alum, or when the beam was used without sifting That the amylic nitrite undergoes decomposition is proved by the formation of brown fumes of nitrous acid Sunlight produces similar effects The author proves, in the next place, that the decomposition is effected by the more refrangible rays of light, and that liquid amylic nitrite is most potent in arresting the rays which affect its vapour This seems to show that the absorption takes place in the atoms, and not in the molecules The author anticipates wide, if not entire, generality for the fact that a liquid and its vapour absorb the same rays When the tube is filled with a rare and well mixed vapour, the electric light develops a blue colour, which may be pure and deep, or milky, according to the intensity of the light Various other liquids were tried with success In many cases the condensed vapours formed extremely beautiful and regularly shaped clouds, the particles rotating around the axis of the tube, or round other axes When the quantity of nitrite vapour is considerable, and the light intense, the chemical action is exceedingly rapid, the particles precipitated being so large as to *whiten* the luminous beam Not so, however, when a well mixed and highly attenuated vapour fills the experimental tube The effect, now to be described, was obtained in the greatest perfection when the vapour of the nitrite was derived from a residue of the moisture of its liquid, which had been accidentally introduced into the passage through which the dry air flowed into the experimental tube In this case the electric beam traversed the tube for several seconds before any action was visible, decomposition then visibly commenced and advanced slowly The particles first precipitated were too small to be distinguished by a hand lens, and when the light was very strong, the cloud appeared of a milky blue When, on the contrary, the intensity was moderate, the blue was pure and deep In Brucke's important experiments on the blue of the sky, and the morning and evening red, pure mastic is dissolved in alcohol, and then dropped into water well stirred. When the proportion of mastic to alcohol is correct, the resin is precipitated so finely as to elude the highest microscopic power By reflected light such a medium appears bluish, by transmitted light yellowish, which latter colour, by augmenting the quantity of the precipitate, can be caused to pass into orange or red, but the development of colour in the attenuated nitrite of amyl vapour, though admitting of the same explanation, is, doubtless, more similar to what takes place in our atmosphere The blue, moreover, is purer and more sky-like than that obtained from Brucke's turbid medium. The results obtained with hydriodic acid are of so startling and unprecedented a character, that we consider it important to give them in Professor Tyndall's own words, as follows —"I have seen nothing so astonishing as the effect obtained, on the 28th of October, with hydriodic acid. The cloud extended for about 18 inches along the tube, and gradually shifted its position from the end nearest the lamp to the most distant end The portion, quitted by the cloud proper, was filled by an amorphous haze, the decomposition, which was progressing lower down, being here, apparently, complete. A spectral cone turned

its apex towards the distant end of the tube, and, from its circular base, filmy drapery seemed to fall Placed on the base of the cone was an exquisite vase, from the interior of which sprang another vase of similar shape, over the edges of these vases fell the faintest clouds, resembling spectral sheets of liquid From the centre of the upper vase, a straight cord or cloud passed for some distance along the axis of the experimental tube, and at each side of this cord two involved and highly iridescent vortices were generated. The frontal portion of the cloud, which the cord penetrated, assumed in succession the forms of roses, tulips, and sunflowers It also passed through the appearance of a series of beautifully shaped bottles, placed one within the other Once it presented the shape of a fish, with eyes, gills, and feelers. The light was suspended for several minutes, and the tube and its cloud permitted to remain undisturbed in darkness On re-igniting the lamp, the cloud was seen apparently motionless within the tube, much of its colour had gone, but its beauty of form was unimpaired. Many of its parts were calculated to remind one of Gassiot's discharges, but in complexity, and indeed in beauty, the discharges would not bear comparison with these arrangements of cloud A friend, to whom I showed the cloud, likened it to one of those jelly-like marine organisms, which a film, barely capable of reflecting the light, renders visible. Indeed no other comparison is so suitable, and not only did the perfect symmetry of the exterior suggest this idea, but the exquisite casing and folding of film within film suggested the internal economy of a highly complex organism. The *twoness* of the animal form was displayed throughout, and no coil, disk, or speck existed on one side of the axis of the tube, that had not its exact counterpart at an equal distance on the other I looked in wonder at this extraordinary production for nearly two hours" (See *Chemical Action of Light*)

CHEMISTRY A definition has been named a metaphorical word, signifying literally, "laying down a boundary," and intended to explain a term, so as to *separate* it from everything else, as a boundary separates one field from another It is difficult so to separate chemistry from other sciences since it is always shifting or enlarging its boundaries and encroaching upon other sciences Not that definitions of chemistry are wanting, for they are almost as numerous as the older Handbooks and Treatises on the Science The very term itself is of unknown origin. It is probably derived from *Alchemy*, or more properly *Al kemy*, from the Arabic word *Kyamon*, "the substance or constitution of anything" Hence Alkemy is the knowledge of the substance or composition of bodies, and chemistry, "the wise daughter of a foolish mother," is derived from Alkemy

But chemistry was not born wise she had to pass through a long period of foolishness before she attained to that wisdom which now excites the admiration of mankind Her educators had to renounce the foolish notions of the parent, and endeavour to apply the idea of analysis to matter as they had been from an early period to words, namely, to resolve these into their component letters, that into its simplest forms Men possessed the fundamental ideas of *element* and *substance* long before they learnt to express them clearly By a multiplication of facts they gradually perceived that there existed a peculiar relation of the elements to their compounds, but they were slow to perceive that compounds could possibly differ in properties from those of the elements that formed them Their notion was that compounds derive their properties from their elements by *resemblance.* They could not conceive an acid body, for example, not to confer acid properties on the compound The four elements—*fire*, *air*, *earth*, and *water*—existed on the notion that bodies were *hot* or *cold*, *dry* or *moist*, and on this distinction was based, during a long period, the practice of medicine Diseases were classed as *hot* or *cold*, &c, and the remedies were arranged to meet this view While the Iatro-chemists (or those that applied their science to medicine) were thus working, innumerable processes in the useful arts contradicted their theory by showing, every day, how useless it was to expect to find in compounds the resemblances of their components. The workers in metal, the tanner, the brewer, the vintner, all bore testimony to the contrary, and it was not until the idea of the four elements was superseded by the doctrine of the *three principles*, salt, sulphur, and mercury, that chemistry began to advance, and then it was by the recognition of the fact that compounds, unlike the materials used, are the result of the union and the separation of matter, men slowly realized the idea that substances are not necessarily like what they make

But the teaching of the "foolish mother" still lingered The fanciful idea yet prevailed, that the products of bodies depend on the *forms* of their ultimate particles, such as round or angular, pointed or hooked, straight or spiral. The particles of a sweet substance were supposed to be round and smooth, those of an acid, sharp and jagged Even the philosophy of Descartes and of Gassendi was tainted with this doctrine That respectable writer Lemery says, that "no one will dispute that an acid *must* consist of sharp-pointed particles, which prick the tongue like anything sharp and finely cut Moreover, we see that acid salts crystallise into edges. These acid points enter the solid matter of an alkali which is adapted to their form," much, we

may suppose, as the sheath is adapted to the sword Even Dr Mead, so late as 1745, refers to the lamellæ or blades which constitute the poisonous effect of corrosive sublimate.

Another idea, which has retarded the progress of chemistry, refers the chief force in the formation of compounds, to the mechanical attraction of the elements. This idea arose out of the Newtonian philosophy Newton himself speaks of "certain forces by which the particles of bodies, through causes not yet known, are either urged towards each other and cohere, according to regular figures, or are repelled and recede from each other When, for example, salt of tartar runs *per deliquium* [deliquesces], is not this done by an *attraction* between the particles of the salts and the particles of the water which float in the air in the form of vapours? And why does not common salt, or saltpetre, or vitriol, run *per deliquium*, but for want of such an attraction?" Other cases are given by the same great authority to show that chemical combinations act by a mechanical attraction of particles. Many of Newton's disciples, unmindful of the cautious habits of thought of the master, pushed this notion beyond the limits of sound theory, and explained the formation of compounds as the mere mechanical attraction of particles, forgetting that this is quite inadequate to explain changes of colour, transparency, texture, taste, odour, &c., due to small changes in the ingredients. Thus, in a work dedicated to Newton, Dr Frend, in 1710, adopts the mechanical idea of attraction in the formation of all compounds "That force of attraction," he says, "of which you first so successfully traced the influence in the heavenly bodies, operates in the most minute corpuscles, and this force we are only just beginning to perceive and to study" But Newton (as if anticipating the modern fiction of Frankenstein) was startled at the effects of his own work, for he says, "The parts of all homogeneal hard bodies which fully touch each other stick together very strongly, and for explaining how this is, some have invented hooked atoms, which is begging the question." For, he would ask, how do the parts of the hook cohere?

As time advanced, it was seen that no mechanical force can account for changes of colour, texture, odour, &c , that bodies cannot consist of elementary particles exerting forces of the same nature as the central forces considered in mechanics It was admitted that the force which produces combination is a peculiar principle, a special relation of the elements, not correctly expressed in mechanical terms This peculiar principle was named *Affinity*, which signifies a disposition to combine—to form an alliance similar to that of marriage—accompanied by the further idea, that where there is marriage, divorce (analysis or separation) is possible. This was clearly shown by Mayow as early as 1674 He proved that where opposite elements, such as an acid and an alkali combine, their properties disappear, and a new substance is formed not resembling the ingredients. He says, "Although these salts thus mixed appear to be destroyed, it is still possible for them to be separated from each other with their powers still entire" He clearly points out the two great chemical processes—*Analysis* and *Synthesis* He also showed that affinity is *elective* "I have no doubt," he says, "that fixed salts choose one acid rather than another, in order that they may coalesce with it in a more intimate union"

The next idea that greatly promoted the advance of chemistry was, that affinity is *definite* as to quantity Rouelle, in 1742, speaks of salts with excess either of acid or of base, and of perfectly neutral salts When the balance became part of the necessary furniture of every laboratory, it was found that the proportional weights of the ingredients of every neutral compound were always the same, as was shown by Wenzel in 1777 The same idea was taken up by Richter in 1792, and led to the *Atomic Theory* of Dalton in 1803

Did the nature of this work admit of long articles, we might go on to show how chemistry advanced by the confirmation of definite ideas as to the indestructibility of matter, and on such important principles as that a body is equal to the sum of its elements, that chemical composition determines physical properties We should also have to mark such eras in the science as the discovery of oxygen gas, and the destruction of the *phlogiston* hypothesis, the discovery of the composition of water, and the foundation of pneumatic chemistry.

It would not be possible to pursue this mere indication of the progress of chemistry without encountering details of sufficient extent and importance to fill a volume Hence it will not excite surprise that modern writers of handbooks, &c, on chemistry do not attempt to define the science, but prefer to state its objects These are given in Professor Miller's *Elements* in the following terms.—"1 To resolve matter into its simplest components 2 To ascertain the properties of these simple or elementary forces of matter 3 To combine two or more of these elementary bodies with each other, so as to form compounds 4 To study the properties of these compounds, and, 5. To define the conditions under which such compounds can exist" These objects are embraced by *pure*, *theoretical*, or *philosophical* chemistry This again may be divided into *organic* and *inorganic* chemistry, and the former into *animal* or *vegetable* chemistry, and the latter into *metallurgic*, *agricultural*, *medical*, &c , chemistry.

Chemistry also partakes of the nature of an *art* as well as a science, when it puts forward

certain rules and mechanical methods for effecting the objects above enumerated This is *practical* chemistry We also speak of *synthetical* chemistry, which treats of the union of bodies into well-defined compounds, *analytical* chemistry, which (1) detects the several constituents of a component body, and (2) estimates their quantities, (1) being termed *qualitative*, and (2) *quantitative analysis* There is a branch of analytical chemistry known as *assaying* or *docimacy*, which is the *art* of detecting and estimating the precious metals in their various compounds *Applied chemistry* is the application of chemical principles to the various substances used in ordinary life, such as *pharmaceutical* chemistry, which relates to the preparation of substances used in medicine, *technical* chemistry, which relates to arts and manufactures, and this admits of a large number of subdivisions, the chemistry of glass-making, dyeing, the smelting of metals, soda-making, &c &c, requiring special knowledge of particular branches of this vast science

CHEMISTRY OF SOILS See *Soils, Chemistry of*

CHEVAL-VAPEUR The French unit by which rates of work of machines are compared One such unit represents the work performed in raising seventy-five kilogrammes through one metre in a second It is nearly equivalent, therefore, to the English "horse-power," the latter being 33,000 foot-pounds per minute, and the former nearly 32,500 foot-pounds per minute. (See *Foot pound, Kilogrammetre, and Horse-power*)

CHEVREUL'S CHROMATIC CIRCLE · This consists of a series of seventy two tints passing gradually into one another, and each modified by twenty shades varying from almost white to almost black. The whole diagram, therefore, consists of 1440 colours, and by referring to these by number some approach towards a standard nomenclature of colour may be obtained The name is from that of the French savant who first devised it See Watt's *Dictionary of Chemistry*, article Light, page 652 Also Guillemin's *Phenomènes de la Physique*

CHILE SALTPETRE See *Nitrates, Nitrate of sodium*

CHIMES, ELECTRIC An electric toy used for illustrating attraction and repulsion It consists of three small bells suspended in a row from a brass rod The two extreme bells are suspended by means of brass chains, the middle one by a silk thread Thus when the brass rod is hung by a hook from the prime conductor of the machine the extreme bells are in connection with the prime conductor and the middle one is not A chain is brought from the earth to the latter Between the bells are two little brass balls hung by silk threads in the same line with them When the machine is turned the extreme bells are charged, they attract the brass balls which swing toward them and strike against them On doing so the balls become charged by contact and are then repelled by the extreme bells and attracted by the bell connected with the earth and swinging up against it they discharge themselves, then back again to the extreme bells, and so on, ringing the bells all the time

CHLADNI'S FIGURES These are the figures formed by sand which is strewn upon a horizontal plate clamped at one point and set in vibration by a violin bow The formation of the figure is an immediate consequence of the formation of nodal lines or lines of rest If the plate be square and clamped in the middle, the lowest or fundamental note is produced when the plate vibrates in four segments If the finger be lightly placed at one corner and the bow be drawn across the edge at the centre of one of the adjacent sides, the only lines of rest will be the two diagonals These will divide the square into four segments, of which the two opposite ones are always in the act of ascending or descending together, while the neighbouring segments are so related that when one is going up its neighbours are going down, and *vice versa* The particles of sand are tossed about as long as they are upon the moving segments, but when they fall upon the nodal lines (in this case the diagonals) they remain at rest The result is that the sand quickly accumulates on these lines A square plate may also be made to vibrate in four segments by touching the centre of one of the sides with the finger and drawing the bow across the corner The nodal lines in this case are the two straight lines joining the centres of the opposite sides If, in either of the above cases, the finger being placed as before, the bow be drawn more lightly and rapidly it is possible to make the plate sound the higher octave This is immediately exhibited by the nodal lines, four curved fresh lines not crossing the original ones being produced, so that the whole plate is divided into eight segments By varying the points at which the finger is placed and the bow drawn a countless variety of figures of great beauty may be produced. The number may be further increased by varying the point at which the plate is clamped. In all cases, the point touched by the finger, and all symmetrically situated points, are the extremities of nodal lines, while the point scraped by the bow and all symmetrically situated points are in maximum vibration The relation between the pitch of the note and the number of segments in which the plate is divided is well shown by means of a circular dish clamped in the centre If the finger and bow are one-eighth of the circumference apart the segments are four in number and the fundamental note is produced. If the distance between the two is one-sixteenth of the circumference the higher octave is produced and so on.

Circular segments may be obtained by clamping the circular disk eccentrically, making a hole in its centre and drawing a few horse hairs through it The point where the plate is clamped will be a point on the nodal circle The same effect may be shown in a more striking manner by fastening a rod of wood or brass to the centre of the disk and (holding the rod in the middle) setting it in longitudinal vibration by rubbing it with resined leather Sand strewn on the disk will arrange itself in the rings of nodal lines which will be more numerous the shorter is the rod Sand figures produced in any of these ways can be rendered permanent by transferring them to blackened paper, the surface of which has been moistened with gum If iron filings are used instead of sand, they may be exposed to the vapour of nitro-hydrochloric acid until some perchloride of iron is formed, then a piece of white paper moistened with ferro-cyanide of potassium is pressed upon them, the filings print themselves in Prussian blue

CHLORAL (So named to indicate its origin from *chlorine* and *alcohol*.) A colourless oily looking fluid of a peculiar penetrating odour, soluble in alcohol, water, and ether It is prepared by passing dry chlorine into anhydrous alcohol, a copious evolution of hydrochloric acid takes place, and chloral (C_2Cl_3HO) is formed When a small quantity of water is added to chloral, they unite, forming a crystalline compound of considerable stability in the air When chloral, or its hydrate, is mixed with a caustic alkali, it is immediately decomposed into a formeate and chloroform Kept in the anhydrous state for a few days, chloral gradually changes to a white mass like porcelain, without, however, any alteration in chemical composition *Hydrate of chloral* is of considerable value in medicine, as it is a very powerful hypnotic, rapidly producing sound and refreshing sleep, whilst it does not appear to be followed by injurious reaction

CHLORIC ACID See *Chlorine*

CHLORIDE OF LIME See *Chlorine*, *Hypochlorites*

CHLORINE (χλωρος, green) A yellowish green gas, of a very pungent and suffocating odour. Specific gravity about 2 5, atomic weight 35 5, symbol Cl When condensed by a pressure of four atmospheres it becomes a yellow liquid of specific gravity 1·33 The gas dissolves in half its volume of water, forming a faint yellow solution, with the peculiar smell of chlorine. When passed into water which is near the freezing point, a *Hydrate of chlorine* ($Cl\,5H_2O$) separates in crystals In its chemical properties chlorine is very energetic, uniting directly with many other elements, sometimes with incandescence, as, for instance, with phosphorus, arsenic, antimony, &c , and also with many organic compounds, its principal action being to unite with hydrogen to form hydrochloric acid Its affinity for hydrogen is one of its strongest characteristics, it decomposes water with separation of oxygen, and thus indirectly acts as a powerful oxidising agent, hence chlorine is of great value in destroying organic colouring and other matters, and also as a bleaching agent and disinfectant Chlorine is prepared by oxidising hydrochloric acid, by heating it with binoxide of manganese The compounds of chlorine are very numerous and important, those which are not described below will be found under the name of the other element of the compound

The oxygen compounds of chlorine are *Hypochlorous acid*, *Chlorous acid*, *Chloric acid*, *Perchloric acid*, besides other oxides of unimportant properties, and less definite composition

Hypochlorous Acid, a pale reddish yellow gas, with an odour strongly resembling that of chlorine Formula Cl_2O, when slightly heated it decomposes with explosion, it dissolves in water, forming a yellowish solution, with an acid reaction, it possesses strong bleaching properties, and unites with bases to form salts Three of these, the calcium, sodium, and potassium salts are of great use as bleaching substances and disinfectants

Hypochlorite of Calcium (ClCaO), known as *chloride of lime* A dry white powder, of a peculiar chlorous smell, and strong bleaching and disinfecting properties, somewhat soluble in cold water, but decomposing when heated. It is formed, on the large scale, by passing chlorine gas over slaked lime to saturation

Hypochlorite of Sodium The compound known under this name is a mixture of hypochlorite and chloride of sodium, it is prepared by passing chlorine gas through caustic soda, or by decomposing chloride of lime (Hypochlorite of calcium) with carbonate or sulphate of sodium

Hypochlorite of Potassium, or *Eau de Javelle*, is prepared in a similar manner to the above, it is also similar in composition and properties The hypochlorites of magnesium, aluminium, and zinc have also been proposed for use as bleaching agents

Chlorous Acid (Cl_2O_3) is a yellowish green gas, very similar to hypochlorous acid; it forms salts with bases, but they are unimportant

Chloric Acid ($HClO_3$) A colourless syrupy liquid, strongly acid, and very powerful as an oxidising and bleaching agent With bases it forms well-defined salts, which are decomposed

by heat with evolution of oxygen, and detonate when heated with combustible bodies, the most important of these are the following:—

Chlorate of Barium ($BaClO_3$). This forms large prismatic colourless crystals, which decrepitate and melt when heated to a temperature approaching redness, the salt is readily soluble in water, it is much used in pyrotechny, as it produces an intense green light when it is heated with sulphur or other combustibles.

Chlorate of Potassium ($KClO_3$). A salt which crystallises in large six-sided plates, quite permanent in the air, and soluble in water, when heated it fuses, evolving oxygen, and leaving a residue of chloride of potassium. It is largely used in laboratories as a source of oxygen gas. When mixed with combustible substances such as sulphur, antimony, or phosphorus, and struck with a hammer, the mixture detonates, when mixed with some other combustibles, and touched with a drop of concentrated sulphuric acid, the whole ignites with a bright flash, when added to strong sulphuric acid, gaseous peroxide of chlorine is given off, which ignites combustible bodies, when heated with strong nitric acid, a mixture of chlorine and oxgyen is evolved, and with strong hydrochloric acid, a mixture of peroxide of chlorine and chlorine. Chlorate of potassium is largely used as an oxidising agent in the laboratory, and in some manufacturing operations, in calico printing, for instance, and it is also used in the manufacture of lucifer matches, fireworks, and percussion caps.

Perchloric Acid ($HClO_4$). In the pure state this is a colourless oily liquid, very volatile, and easily decomposed. Specific gravity 1 782. It is, perhaps, the most powerful oxidising agent known, a single drop brought in contact with charcoal, or other combustible body, induces combustion with explosive violence. It unites energetically with water, forming a *hydrate* ($HClO_4H_2O$), a white solid crystalline substance melting at 50° C (122° F). This is almost as violent in its oxidising powers as the anhydrous acid. Perchloric acid unites with bases to form well defined salts, which are, for the most part, very soluble in water, the only one which need be mentioned is *Perchlorate of Potassium*. This is formed by carefully heating chlorate of potassium to a little above its fusing point, after a short time oxygen ceases to come off, and the liquid mass becomes pasty. From this, perchlorate of potassium is obtained by crystallisation, it is sparingly soluble in cold water, and decomposes at a dull red heat into chloride of potassium and oxygen.

Chlorhydric Acid (HCl). See *Hydrochloric Acid*.

Chlorides. Chlorine unites with almost every other element, and with numerous organic compounds, such as organo-metallic radicals, alcohol radicals, aldehyd radicals, and acid radicals. All chlorides, which are of importance, will be found described under their respective names, those of the metals being given under their headings.

CHLORINE, SPECTRUM OF. The absorption lines, produced by the passage of the solar light through chlorine, have been examined by Morren, (*Comptes Rendus*, lxviii, p 376). He has found that by employing a spectroscope of five prisms of highly dispersive flint glass, absorption lines are distinctly visible in the spectrum of light which has traversed a tube filled with chlorine, two meters in length. The lines begin to be visible in that part of the spectrum near B. They vary in intensity, fineness, and mode of grouping, and exhibit some slight free spaces. They have no regular order, and extend beyond the ray F, towards the ray 2110 of Kirchhoff's scale. In this last portion they are very numerous, and almost equidistant. The solar spectrum proper continues visible as far as 2210, but after that the light is completely absorbed. Chlorine therefore absorbs the coloured portion of the spectrum where the chemical rays are most abundant. (See *Spectrum*.)

CHLOROCHROMIC ACID. See *Chromium*.

CHLOROCODIDE. By acting on codeia with a great excess of hydrochloric acid at a high temperature *apomorphia* is produced, but by a modification of the experiment Messrs Matthiessen and Wright obtained a base which they call chorocodide, of the composition $C_{18}H_{20}ClNO_2$. It has no marked physiological action. (Proc R S xviii, p 83.)

CHLOROFORM, or *Perchloride of Formyl*. A transparent, colourless oily liquid, which boils at 61° C (142° F), and distils without change. Specific gravity 1 49. The odour is pleasant and ethereal, and when inhaled the vapour rapidly produces unconsciousness and insensibility to pain, on this account chloroform is extensively used as an anæsthetic in surgical operations. Chloroform is slightly soluble in water, and mixes in all proportions with alcohol and ether. It dissolves phosphorus, sulphur, iodine, and many organic bases. The formula of chloroform is $CHCl_3$, it is prepared on the large scale by distilling bleaching powder (hypochlorite of lime) with alcohol.

CHLOROPHYLL. The green colouring matter of leaves. In the purest state in which it has been obtained, it is a dark green powder unaffected by any heat below 200° C (392° F.), insoluble in water, slightly soluble in ether, and more so in alcohol. Acids and alkalies dissolve

it. The formula has not been satisfactorily determined Some observers consider that it contains iron, and has some resemblance to the colouring matter of the blood, others, however, do not admit this

CHLOROPLATINATES Compounds of platinic chloride and other chlorides are called chloroplatinates. These double salts usually crystallise with great facility, and are difficultly soluble in water The chloroplatinates of organic bases are usually employed for the purpose of fixing their composition, as they are prepared and purified with great facility, and on ignition leave pure platinum The following chloroplatinates deserve mention —

Chloroplatinate of Ammonium $(NH_4)_2PtCl_6$ This is a lemon-yellow powder, almost insoluble in water, which is precipitated when chloride of ammonium is added to platinic chloride. On ignition it leaves spongy platinum

Chloroplatinate of Potassium, K_2PtCl_6, much resembles the ammonium salt. It is very sparingly soluble in water

The *Chloroplatinates of Cæsium* and *Rubidium* have similar composition to the above, and are still less soluble in water An aqueous solution of chloroplatinate of potassium is sometimes used as a test for the presence of both rubidium and cæsium.

Chloroplatinate of Sodium is easily soluble in water, and crystallises in light yellow prisms Platinic chloride is used in quantitative analysis as a means of separating potassium from sodium

CHOKE DAMP See *Carbon, Carbonic Acid*

CHOLESTERIN A fatty substance extracted from gall stones, it occurs in bile, blood, brain, yolk of egg, &c It is a white, tasteless, inodorous substance, crystallising in pearly scales, insoluble in water, but easily so in hot alcohol, from which it separates in crystals on cooling Formula $C_{26}H_{44}O$ It melts at 137° C (279° F), and distils at 200° C. (392° F) without alteration

CHORD In music the union of two or more sounds produced at the same time in consequence of the recurrent coincidence at short intervals of their constituent vibrations (See *Harmony*)

CHOROID COAT (χοριονα, membrane, and εἶδος, form) A delicate membrane lining the inner surface of the sclerotic coating of the eye (See *Eye*)

CHROMATES Combinations of chromic acid with bases are called chromates, the most important are the following —

Chromate of Barium $(BaCrO_4)$ A pale, yellow powder, insoluble in water, sometimes used as a pigment

Chromate of Lead $(PbCrO_4)$—This is found native in translucent reddish yellow crystals, known under the name of red lead ore. Artificially prepared it is a yellow, insoluble powder, which varies in shade according to the mode of preparation, and is much used as a pigment under the name of *Chrome Yellow.* A basic chromate of lead $(Pb_2O\ 2PbCrO_4)$, is also prepared as a pigment by heating the neutral chromate with alkalies It is of a deep orange red colour, and is known as *Chrome Red*

Chromates of Potassium —These are prepared on the large scale, and are much used in the arts and manufactures The neutral or yellow chromate of potassium forms six-sided pyramids of a pale lemon-yellow colour, soluble in about twice its weight of cold water, much more so in hot water, and insoluble in alcohol Acid chromate of potassium $(K_2O\ 2Cr_2O_3)$, known also as *Bi-chromate of Potash* or *Red Chromate of Potash* Crystallises in rich red prisms, which are permanent in the air It dissolves in ten times its weight in cold water, and in less of hot At a little below redness it melts, and on cooling solidifies without altering in composition. It is a powerful oxidising agent, and is largely employed in dyeing and calico printing, and in the preparation of coloured pigments

Chromate of Silver $(AgCrO_4)$, a scarlet insoluble powder, precipitated when a soluble chromate is added to nitrate of silver

CHROMATIC CIRCLE, CHEVREUL'S. (χρωματικος—χρωμα, colour, χρωννυμι, to stain) See *Chevreul's Chromatic Circle*

CHROMATIC DYNAMOMETER See *Dynamometer, Chromatic*

CHROMATICS That branch of the science of optics which relates to colour The spectrum is a chromatic scale of colour

CHROMATOSCOPE See *Scintillation.*

CHROME ALUM. See *Alum*

CHROME IRON ORE See *Chromium.*

CHROME RED See *Chromates, Chromate of Lead.*

CHROME YELLOW. See *Chromates, Chromate of Lead*

CHROMIUM. (χρωμα, colour) A metallic element discovered by Vauquelin. Symbol

Cr. Atomic weight 26 2 It is almost unknown in the metallic state Its compounds are remarkable for their numerous and brilliant colours, whence its name The most abundant native compound is *chrome iron ore*, a combination of oxides of iron and chromium, of the formula, when pure, $Fe_2O\ Cr_4O_3$ Chromium forms several oxides, the *protoxide*, Cr_2O, the *sesquioxide*, Cr_4O_3, *chromic acid*, Cr_2O_3, and *perchromic acid*, Cr_4O_7 The protoxide is very unstable and forms salts which are but little known. The sesquioxide in the anhydrous state is a dark green powder, sometimes in rhombohedral crystals When gradually heated it suddenly becomes incandescent and is then almost insoluble in acids In the hydrated state it is a lighter green powder, soluble in fixed caustic alkalies, forming a green solution, and reprecipitated on boiling, it is also soluble in acids The amount of water it contains depends on the manner of preparation Its salts appear to exist in two modifications—green and violet

Chromic Acid, forms scarlet needle-shaped crystals which are deliquescent in damp air, they melt at 190° C (374° F) and give off oxygen at a higher temperature, being reduced to the sesquioxide Organic substances also rapidly reduce it to the same compound Chromic acid forms salts with bases (See *Chromates*)

Perchromic Acid A blue substance known only in solution, formed when peroxide of hydrogen is mixed with a solution of chromic acid It appears to form violet salts, which are readily decomposed Owing to the intensity of the blue colour this reaction with peroxide of hydrogen is sometimes used as a test for chromium

Chlorides of Chromium The only chloride of importance is the *sesquichloride* (Cr_2Cl_3), which forms shining laminæ of a beautiful peach colour, insoluble in cold water, but soluble in hot It sublimes at a high temperature The aqueous solution is dark green and gives the reactions of solutions of sesquioxides of chromium

Oxychloride of Chromium or *Chlorochromic Acid* ($Cr\ Cl_3\ Cr_2O_3$) is a deep blood red, almost black, liquid, formed by distilling a mixture of chromate of potash, chloride of sodium, and strong sulphuric acid Specific gravity 1·71 Boiling point 118° C (244 5° F) It sets fire to easily combustible bodies, and is decomposed by water into chromic and hydrochloric acids

CHROMO-PHOTOGRAPHY That branch of the photographic art which relates to the production of photographs in their natural colours Many attempts have been made to produce photographs in natural colours, this has been partially accomplished by Nièpce de St Victor, E Becquerel, and others, and tolerably truthful representations of coloured objects and even the solar spectrum have been exhibited by these experimentalists, but all attempts to render them permanent have hitherto failed, exposure to light gradually obliterates them (See *Photography*)

CHROMOSPHERE (χρῶμα, the colour of the skin, σφαῖρα, a sphere) The name given by Mr Lockyer to a solar envelope first fully recognised by Secchi "The observation of eclipses," says Secchi, "furnishes indisputable evidence that the sun is really surrounded by a layer of red matter, of which we commonly see no more than the most elevated points"—*Etudes Religieuses, Historiques, et Litteraires*, August 1867 The spectroscopic observations of Mr. Lockyer supply abundant evidence of the justice of Secchi's view

CHRONOLOGY (χρονολογία) The science which treats of the different divisions of time, whether as relating to astronomical or other events. The astronomical relations of chronology are considered chiefly under the heads *Bissextile*, *Calendar*, *Cycle*, *Year*, &c Historical chronology is only related to the subjects treated of in this work, in so far as certain historical events have been associated with such astronomical occurrences as solar or lunar eclipses, occultations, the appearance of comets, and the like But even those relations cannot be considered here, as their due treatment requires much more space than is available, besides involving a multitude of considerations which lie wholly apart from the scope of this work

CHRONOMETER (χρόνος, time, and μέτρον, measure) A watch constructed with special care to ensure accurate time measurements during long intervals of time For this purpose a number of contrivances are made use of, the chief having reference, first, to the effects accruing from variations of temperature, and secondly, to the effects resulting from the varying action of the motive force We owe to Harrison the first successful construction of accurate time-keepers It need hardly be said that the chronometer is an instrument of first-rate importance to the seaman undertaking long voyages. (See *Longitude, Determination of*)

CHRONOSCOPE. (χρονος, time, σκοπεω, to examine) An instrument invented by Wheatstone for the purpose of determining the duration of the electric spark, and the velocity of electric discharge It is founded on the optical effect known as *persistence* of the image on the retina; that, in fact, which gives rise to the appearance of a line of light when a stick with a burning point is whirled in the air In Wheatstone's instrument a small mirror was caused to rotate with enormous angular velocity round an axis in its own plane, and the image of the

spark or other luminous object was observed in it Under these circumstances, if the illumination be instantaneous, the image will appear as a mere spot of light, precisely the same as if the mirror were at rest, but if it lasts for any time, then the mirror, moving on in the interval, gives rise to an image extended out into a *line of light* This may readily be observed by any one who takes a mirror in his hand, and either waves it about or makes it revolve in front of a candle. It is easily shown by geometry that, in the case of a revolving mirror, the angular displacement of the image is twice that of the mirror If, then, the length of the line of light be measured, and if the velocity of rotation of the mirror be known, the duration of the spark is calculable By means of the chronoscope, Wheatstone showed that an ordinary spark from an electric machine, or from a Leyden jar, discharged in the common way, lasts less than the millionth of a second, but that, in the latter case, if the discharge takes place through half a mile of copper wire, the spark lasts for a sensible time The instrument has also been employed to demonstrate the discontinuity of certain flames.

CHRYSANILINE See *Aniline*

CHRYSEONE See *Silicon*

CILIARY BODY, or PROCESS (*Cilium*, κυλα, eyelashes, hair) The muscular fibres which hold the crystalline lens, and by their contraction cause its curvature to be altered for distinct vision (See *Eye*)

CINCHONA BARK, ALKALOIDS FROM The organic alkaloids contained in these barks consist of quinine, cinchonine, cinchonidine, and quinidine, together with quinotannic, quinovic, and quinic acids Of these the quinine is by far the most important, and is generally present in the largest proportion, although in some barks it is almost entirely replaced by cinchonine The percentage of quinine in the dried bark is sometimes as high as 3 7 per cent, and at others as low as 0 1 per cent or less The methods of extracting quinine and the other valuable constituents are somewhat complicated Their preparation is conducted on a very large scale in many parts of the world, and so greatly is a "quinine famine" dreaded in tropical countries, that energetic steps have been taken by the government of India to introduce the cultivation of the cinchona plant into various parts of that country where it has not hitherto grown, whilst other governments are adopting similar measures to spread its cultivation elsewhere In localities where epidemic fevers are prevalent, the price of quinine has been known to rise from a few shillings per ounce to upwards of £20 per ounce Owing to the great value of the cinchona alkaloids in medicine, attempts have repeatedly been made to prepare them artificially, and there is little doubt that this will some day be accomplished, although hitherto the attempts have not been successful For a description of the principal alkaloids, see separate articles

CINCHONIDINE An organic alkaloid sometimes accompanying quinine and cinchonine in cinchona barks It is very sparingly soluble in water, but tolerably so in alcohol The formula is not quite settled, but it is supposed by Pasteur to be isomeric with cinchonine It forms hard anhydrous rhombic crystals, which have a bitter taste. They melt at 347° F, and decompose at a higher temperature

CINCHONINE An organic alkaloid existing in cinchona barks, together with quinine Formula $C_{20}H_{24}N_2O$ It crystallises in brilliant colourless four-sided needles, insoluble in water and ether, and only slightly so in alcohol and chloroform The solutions have an alkaline reaction and a bitter taste When heated to 330° F, it melts to a colourless liquid, and at a higher temperature sublimes with partial decomposition It forms salts with acids, which are for the most part crystalline, and soluble in water Cinchonine and its salts are sometimes used in medicine as a febrifuge, but their effect is much inferior to that of quinine

CINNABAR. See *Mercury, Sulphide*

CIRCINUS. (The *Compasses*) An inconspicuous southern constellation formed by Lacaille

CIRCLE, HOUR See *Hour Circle*

CIRCLE OF THE CELESTIAL SPHERE A circle in which any plane intersects the celestial sphere Planes passing through the centre of this sphere meet its surface in great circles, as the *ecliptic, equator, prime vertical* (*q v*), &c Planes not passing through the centre meet the sphere in small circles (See *Parallels*) When the word circle is combined with another term as declination, latitude, or the like, the circle referred to is the great circle on which the declination, latitude, or other element, as the case may be, is measured Thus a *declination-circle* is one which passes through the poles of the heavens, on which, therefore, declinations can be measured. And so for the rest

CIRCLE, RIGHT ASCENSION See *Hour Circle*

CIRCUIT, GALVANIC. A galvanic pair, through which the current is passing forms a complete chain or *circuit*, as it is called. Thus, in a typical case (see *Galvanic Pair*), the current

may be supposed to start from the zinc pass through the liquid to the platinum, and thence through the wire back again to the zinc. When the platinum and the zinc plates are connected by a wire, the circuit is said to be *closed*, and the current then circulates, but when the connection between the plates is not complete, the circuit is then said to be *broken or interrupted*

CIRCULAR POLARISATION. Imagine two rays of light polarised in opposite planes, and superposed one upon the other If the undulation of one is a quarter of a wave length in advance of that of the other, they will interfere and produce a *circular* vibration A ray of light produced in this way possesses very remarkable properties, and it is said to be *circularly polarised* There are several methods of producing circularly polarised light, but the principle is the same—viz, plane polarised light is doubly refracted in such a way that the two rectangularly polarised waves differ in their phase a quarter of an undulation Comparing the undulations of plane polarised light to a flat ribbon, those of circularly polarised light, or rotatory polarised light, as it is sometimes called, may be compared to a corkscrew Plane polarised light becomes circularly polarised by passing through a plate of quartz, and through many liquids and aqueous solutions. (See *Polarised Light, Polarisation, Plane of*)

If the two rays of light do not differ in phase an exact quarter of an undulation, but some fractional number, the vibratory movement will not be circular, but elliptical, and the ray of light is then said to be *elliptically polarised* The form of the vibration may vary from almost circular to almost plane

CIRCULAR POLARISATION, INDUCED BY MAGNETIC ACTION Faraday discovered that many bodies which in their ordinary state exerted no action on light when examined in the polariscope, became capable of circular polarisation when submitted to powerful magnetic action He placed a piece of heavy glass (Boro-silicate of lead) about two inches square and half an inch thick, having flat and polished edges, between the poles of an electro magnet, so that a polarised ray of light should pass through its length, when the electric current was not passing, the glass acted as an indifferent substance, and if the analyser was turned to zero (giving a black field), the introduction of the glass made no alteration In this condition of things the force of the electro-magnet was developed, and in a second or two the field became luminous, and continued so as long as the electric current was passing On stopping it, and so causing the magnetic force to cease, the light instantly disappeared The character of the action thus impressed on the heavy glass is that of rotation, for when the field has thus been rendered luminous, revolution of the eyepiece more or less to the right or left will cause its extinction When the pole nearest to the observer was north, the deviation of the ray was right handed, and when the direction of the electric current was reversed so as to change the poles, the deviation became left-handed. The same effect, but in a much feebler degree, is produced when a helix of covered wire is used instead of an electro-magnet, and it has been found that this property of rotating the polarised ray under magnetic action, is somewhat general. Bertin (Ann de Chimie, iii xxiii 31), gives the following rotatory power for columns of equal length of various bodies at ordinary temperatures, assuming that of heavy glass as equal to 1 —

Heavy glass,	1·00	Phosphorous chloride,	0 51
Stannic chloride,	0 77	Water,	0 25
Carbonic di-sulphide,	0 74	Alcohol,	0 18
Common flint glass,	0 53	Ether,	0 15

CIRCULAR POLARISATION OF LIQUIDS When certain liquids, such as turpentine, or an aqueous solution of cane sugar, are placed in a tube closed at each end with a plate of glass, and examined in the polariscope, they are seen to possess the property of circularly polarising light, giving, on rotating the analyser, the series of natural colours, and like quartz, the liquid may be right-handed or left-handed By appropriate chemical treatment, liquids originally neutral may have this property conferred upon them, a liquid possessing this property originally may have it removed, and a liquid rotating the plane of polarisation in one direction may be altered so as to turn it the opposite direction As in a column of solution of definite length, the amount of rotation depends on the quantity of active substance dissolved in it, the polariscope may become an agent of quantitative chemical analysis. (See *Saccharometer, Optical, Polarised Light*)

CIRCUMPOLAR STAR (*Circum*, around, and *Polus*, the pole) Stars which complete their circuit around the pole of the heavens without setting Such stars must be at a distance from the pole not exceeding the latitude of the place of observation.

CIRRO-STRATUS See *Cloud*.

CIRRUS See *Cloud*

CISTERN BAROMETER. See *Barometer*.

CITRIC ACID. A colourless crystalline acid present in orange and lemon juice, and in many other fruits. Its formula is $C_6H_8O_7 + H_2O$. It forms large transparent colourless

prisms, which are very soluble in water and alcohol. Its solution has a strong, pleasant, acid taste. It unites with bases forming *citrates*.

CLAMP. (Dutch, *Klamp*, from *Klampen*, to fasten, adjust.) A term applied to pieces of mechanism for holding together parts which have frequently to be fastened and unfastened when in use. The screws which usually form the important part of a clamp are called adjusting-screws. Clamps have a great variety of applications and forms; a joiner, for instance, has a clamp attached to his bench to enable him to fix small portions of his work very firmly. Clamps or adjusting-screws afford ready means of bringing into temporary connection portions of machinery or of scientific apparatus which are usually disconnected.

CLEAVAGE, ELECTRICITY OF. Certain laminated minerals when cleft exhibit, on the faces of cleavage, electric excitement. Thus, if insulating handles be attached to opposite faces of a plate of mica, and if, by means of them, the plate be pulled so as to become cleft in two, it will be found that one of the fresh faces becomes positively, and the other negatively electrified. In many cases also, if plates of such minerals, furnished with insulating handles, be pressed together firmly and then separated, one will be found excited positively and the other negatively. This phenomenon is spoken of as the electric excitement produced by cleavage. (See *Electricity*.)

CLEPSYDRA. (κλεψύδρα, from κλέπτω, to steal, take secretly and artfully; and ὕδωρ, water.) An ancient contrivance by which water was used to measure time. Its principle was essentially similar to that which lies at the root of all our modern methods of time-keeping,—viz., that of mechanical action artificially brought into play. In the clepsydra or water clock, which was invented by the Egyptians, water was caused to flow continuously into a funnel, at the bottom of which was a small aperture. The quantity of fluid passing through this hole measured the lapse of time. Ctesebius, an Alexandrian philosopher, is recorded to have improved the clepsydra. It was constructed in many forms, and in common life employed more generally in winter and at night when the sun dial was not available. It was capable of being brought to a considerable degree of perfection; but very great care and ingenuity were constantly necessary to obviate the inequality of speed with which the fluid ran out, owing (1) to the decrease in the hydrostatic pressure as the fluid diminished in quantity, and (2) the variability in speed under different atmospheric densities and temperatures. Nevertheless it was by the clepsydra that the Egyptians laid down the course of the sun, that Tycho Brahe traced the motion of the stars, that all astronomers made and recorded their observations, before the discovery of the isochronism of bodies in oscillation, and especially of the pendulum, rendered possible the construction of accurate time-pieces.

The clepsydra was first mentioned by Empedocles, who lived in the fifth century before Christ; Aristotle quotes Empedocles on the subject in his treatise De Respiratione. Aristophanes, in his play of the Birds, mentions it as used to time lawyers' speeches in law-courts.

More recently, the late Captain Kater devised an instrument on the same principle as the clepsydra, to obtain exact measure of fractions of a second. Pure mercury, kept at a constant level in the funnel, is the fluid issuing from the aperture; and the stream is caused to flow into a small receiver at the moment of commencement of an observation, and to be turned away at the instant when the phenomenon observed ceases. If then it be known how many grains of mercury issue from the aperture in one second, and the weight of mercury issuing from the funnel during a given observation can be exactly ascertained, we obtain a very accurate measure of the duration of the observation. (See *Horology*.)

CLIMATE. (κλίμα, from κλίνω, to incline.) In its ancient usage this word signified the varying obliquity of the celestial sphere with respect to the horizon in different latitudes. At present it is used to signify the physical habitudes of any country or district with regard to those atmospheric conditions which affect the welfare of its inhabitants. Humboldt has said that "it includes all those modifications of the atmosphere by which our organs are affected—such as temperature, humidity, variations of barometric pressure, the tranquillity of the atmosphere or its subjection to foreign winds, its purity or admixture with gaseous exhalations, and its ordinary transparency—that clearness of sky so important through its influence, not only on the radiation of heat from the soil, the development of organic tissue and the ripening of fruits, but also on the outflow of moral sentiments in the different races."

If the surface of the earth were perfectly uniform, or symmetrically distributed into districts of land and water arranged in zones along latitude parallels, and if the strata of the soil were throughout of like density, radiating power, and elevation, the different climates of the earth would be bounded by latitude-parallels. Under the actual circumstances, however, this is far from being the case. Land and water are distributed in a manner which hardly presents the semblance of law; elevations and depressions not merely of areas of considerable extent, but of

whole countries, are found in each hemisphere, and endless diversities of soil, contour, and distribution, disturb that mathematical uniformity and exactness which could alone produce the co-ordination of climates under latitude-parallels Geographical position, therefore, though of extreme importance in influencing the climate of a country, is not by any means the only circumstance to be considered Its influence, so far as it extends, depends on the different elevation reached by the mid-day sun in different countries It is obvious that the higher the mid-day sun in the sky the greater will be the current of heat poured by him on any given horizontal area exposed to his rays In considering the effect of geographical position, we must consider separately three distinct orders of climate —

First, the *Arctic Climate* Within the arctic regions the sun does not set throughout the twenty-four hours at midsummer, and the nearer the place is to the pole the longer does the sun continue above the horizon. At the pole itself he remains without setting for six months The arctic winter corresponds exactly to the arctic summer The sun does not rise in winter for a period which (leaving atmospheric refraction out of account) is exactly equal in length to the period during which the sun does not set in summer

Secondly, the *Temperate Climate* Outside the arctic zone, and to the limits of the torrid zone, we have these distinguishing characteristics—that, first, the sun never remains for twenty-four consecutive hours above or below the horizon, and, secondly, that he reaches his greatest elevation at mid-day in midsummer Thus throughout the temperate zone the greatest amount of direct solar heat is received by the earth at the time of the summer solstice (though the weather becomes warmer for some time following this epoch) and the least at the time of the winter solstice (though the weather becomes colder for some time following this epoch)

Thirdly, the *Torrid Climate* Within the torrid zone the distinguishing peculiarity is the occurrence of two seasons of greatest heat, the mid-day sun coming some time before summer to the zenith, and again passing that point some time after summer At the equator itself these seasons of greatest heat occur at the equinoxes

Among the causes which tend to disturb the effects which would otherwise follow from the geographical position of a country the following are the most important —

1 *The Effect of Altitude* As we ascend above the sea-level there is found a progressive diminution of temperature This decrease has three causes In the first place, the mere rarity of the air at high levels unfits it for the retention of the solar heat, and still more for the retention of heat radiated from the earth Secondly, as was first pointed out by Dr Erasmus Darwin, the expansion of the air which rises from plains and valleys along mountain-slopes tends largely to increase the cold of the higher regions Sir John Herschel thus succinctly describes the *rationale* of this explanation (independently put forward by Sir John Leslie) — "Suppose the atmosphere of equal temperature throughout and at rest Now let any mass of air at the surface receive an impulse upwards by some external force (not by heating it) It will rise and, in so doing, displace quiescent air above it, which will descend to fill its place, and this process will continue till the upward impulse is extinguished by friction and resistance In rising, air expands, but as the descending air contracts, *pari passu*, the whole disturbed space, when quiet is restored, will be occupied by air as before, and the total pressure will be unaltered But as regards the distribution of *sensible* heat, a great change will have taken place The air which has expanded in ascending has absorbed caloric and grown colder, while that which has contracted in descending has given out just as much, and become hotter The total heat and the total mass remain unchanged, but the equilibrium of temperature is destroyed The lower strata have become warmer than the upper, the density adjusts itself accordingly, and the undisturbed column superincumbent on both is supported as before" The case here supposed is one of frequent actual occurrence, since aqueous vapour in ascending by its levity must drag the air along with it, so that, as Herschel adds, "the mere fact of a circulation of air in the atmosphere, in so far as that circulation is due to the generation and condensation of vapour, or even to the downward mechanical impulse of the fall of rain or snow, must of necessity cause a deficiency of sensible heat in the higher as compared with the lower regions" Thirdly, in the circumstance that elevated regions are farther removed from the heated mass of the earth and nearer to the cold interplanetary spaces, we have a cause of diminished temperature at high levels

2 *The proximity of large masses of water* has an important effect in modifying the climate of a country The temperature of water is more equable than that of the atmosphere, so that the vicinity of a large ocean surface tends to diminish at once the heat of summer and the cold of winter The neighbourhood of ocean currents may have either cooling or heating influences according to the nature of the current Such influences will presently be considered. But there is one way in which the neighbourhood of large masses of water tends constantly to render the climate of a country more genial. The air over countries bordering on such ocean masses

receives more copious supplies of aqueous vapour, and owing to the great specific heat of water, there thus results the accumulation of vast stores of heat to be set free when the aqueous vapour passes into the liquid form The action of aqueous vapour in checking the radiation of the earth's heat into space is also of extreme importance In his "Discourse on Radiation through the Earth's Atmosphere," Professor Tyndall thus speaks of the action of aqueous vapour on the climate of this country —"Aqueous vapour is a blanket more necessary to the vegetable life of England than clothing is to man Remove for a single summer night the aqueous vapour from the air which overspreads this country, and you would assuredly destroy every plant capable of being destroyed by a freezing temperature The warmth of our fields and gardens would pour itself unrequited into space, and the sun would rise upon an island held fast in the iron grip of frost The aqueous vapour constitutes a local dam, by which the temperature at the earth's surface is deepened, the dam, however, finally overflows, and we give to space all that we receive from the sun"

3 *The neighbourhood of ocean currents* exercises a very powerful influence on the climate of a country This is due in part to the mere transference of so much cold or warm water to the neighbourhood of a country, but chiefly to another cause Where there is a cold current, the air above the current becoming cold is unfitted to retain any considerable amount of moisture, and thus when this air passes over an adjoining country, it comes as an evaporating air current, and therefore brings cold On the other hand, over a warm sea-current the air is warm and moisture laden Its warmth and lightness cause it to form a ready channel for winds, which sweep the warm and humid air over adjoining countries, there to give up a large share of its moisture by condensation, and so to become the means of supplying vast stores of heat (See *Convection*)

Humboldt enumerates, among the causes tending to exalt temperature, the following —The vicinity of a west coast in the northern temperate zone, the configuration of a country cut up by numerous deep bays and far penetrating arms of the sea, the relation of the dry land to seas free of ice extending beyond the polar circle, or to a continent of considerable extent which lies beyond the same meridional lines under the equator, or at least in part within the tropics, the rarity of swamps which continue covered with ice throughout the spring, or even into summer, the absence of forests on a dry sandy soil It may be remarked, with reference to one of these conditions, that Humboldt was probably mistaken in supposing that the climate of Europe is warmer than that of Asia, because Africa, with its extensive heat-radiating deserts, lies to the south of Europe on the same meridian, while the Indian ocean lies to the south of Asia If the heat-radiating power of a continent really influenced countries lying to the north, it should tend to lower rather than to raise the temperature, for the ascending currents of air would strengthen the currents of colder air from the north, and these currents (on Humboldt's assumption that the country directly to the north is that affected) would lower the mean annual temperature of the country they passed over It seems clear, however, that Asia is the country chiefly affected by the heat-radiating power of Africa, since the cold currents from the north travel westwards, while the warm return-current from the south has an easterly motion Kaemtz remarks justly that if the effects of oceans and continents were those assigned by Humboldt, we should find in the western parts of America a colder climate than in the eastern parts, whereas the reverse is the case Professor Nichol has expressed similar views, remarking that "The air that rises in Africa blows rather over Asia than Europe The cradle of our winds is not in Sahara, but in America"

It is to be remarked that the mean annual temperature of a country is less important to the welfare of the inhabitants than the extreme range of temperature exhibited in the course of a year Of two countries, which have the same mean annual temperature, one may have a climate most admirably adapted to the welfare of its inhabitants, while the other may have a climate offering such violent extremes of heat and cold, as to render it unfit for all save those of strong constitution

See further, *Rain*, *Isothermal*, *Isochimenal*, *Isotheral*, &c

CLOCKS, ELECTRIC There are several kinds of electric clocks, but there are two principal classes, those in which electricity is the motive power, and those in which the motive power is got from weights or springs, and in which electricity is only used for controlling or governing the motion

Of the first kind there is a common one, in which the motion is obtained by means of an electro magnet, which attracts a soft iron keeper as often as a current is made to pass through it The keeper is connected by levers, with an extremely simple arrangement of toothed wheels which move the hands In order to cause the current to pass at regular intervals into the electro-magnet, the battery contact is made and broken by means of the oscillations of the pendulum of a standard clock. At each swing the circuit passing from the battery round the

electro-magnet is opened and closed, and the soft iron keeper is thus caused to beat seconds, or parts of a second, as the case may be It is evident that the same standard clock may thus be made to give time to any number of secondary clocks

Another clock of the same class is that of Bain, invented in 1840 In it the bob of the pendulum is a soft iron core surrounded by a coil of wire, the extremities of which are carried up the rod of the pendulum The core is made in the form of a short hollow cylinder, with its axis in the direction of the motion of the pendulum Permanent magnets are placed one on each side of it, and arranged so that the like poles are pointing towards each other and so that when the pendulum swings, the hollow core passes a short distance over the pole of each without touching At the top of the pendulum is a *make and break* arrangement, by which a current is sent into the electro-magnet, reversed at each extremity of the swing, and altogether thrown off in the middle part of it The direction of the current is such that the bob is repelled by the nearest permanent magnet, and attracted by the other, it therefore swings over the current is then reversed, and the bob is again repelled by the nearest and attracted by the farthest magnet This pendulum is applied to ordinary clock work Bain intended to work this clock by means of what is called an *earth battery*, which consists of a plate of zinc and a plate of copper sunk deep in the earth, and excited merely by the moisture there, but it was found that the current was so irregular as to render the clock useless

The pendulum, which we have just described, has, however, found an application in the second class of clocks A clock furnished with a pendulum of this kind is kept going as nearly right as possible by ordinary means, the motive power being obtained from weights or springs, and the final adjustment for accuracy is made by means of electricity To do this a standard clock in an astronomical observatory, at certain stated intervals, is caused, by touching a spring, and completing a battery connection, to send a signal to the other clock Suppose such a signal sent every second half minute or minute Then if the clock to be regulated loses or gains a minute fraction of a second between each signal, the bob of its pendulum is not in its proper position when the signal is sent, and it receives from the battery an impulse which accelerates or retards it, as the case may be Clocks of ordinary construction are thus made to go as truly as the astronomical clock from which they take their time This plan is much employed in giving public time in Glasgow and Edinburgh, and with the most satisfactory effect

CLOCKS AND WATCHES See *Horology*

CLOUD A mass of the visible vapour of water suspended in the atmosphere Clouds and fogs are identical in structure, but fogs rest on the earth while clouds are suspended in the atmosphere with a clear space separating them from the earth A large amount of light has been thrown on the nature of clouds, and the laws which regulate their formation and motions, by the recent balloon ascents of Mr Glaisher It has been shown that the air, even at great elevations, is traversed by currents pursuing their course independently Masses of air of different temperatures are thus brought into collision and combine together, and since the combined air cannot retain the same amount of aqueous vapour as the several parts contained before combination, the excess becomes condensed into the form of visible vapour or cloud The following passage, while indicating some of the lessons which we may hope to learn from balloon ascents, shows also how complex is the whole subject It describes Mr Glaisher's ascent from Mill Hill, near Hendon, on August 21, 1862 —"Twenty seven minutes after leaving the earth, a white mist enveloped the balloon, the temperatures of the air and dew-point were alike, indicating complete saturation The light rapidly increased, and gradually emerging from the dense cloud into a basin surrounded by immense black mountains of cloud rising far above us, shortly afterwards there were deep ravines of grand proportion beneath open to the view The sky immediately overhead was dotted with cirrus clouds As the balloon ascended, the tops of the mountain like clouds were tinged with gold and silver On reaching their level the sun appeared, flooding with light all that could be seen both right and left, tinting with orange all the remaining space It was a glorious sight The ascent still continued, but more quickly as the sun's rays fell upon the balloon, each instant opening to view deep ravines and a wonderful sea of clouds Here arose shining masses of cloud in mountain ranges, some rising perpendicularly from the plains with summits of dazzling brightness, some pyramidal, others undulatory Nor was the scene wanting in light and shade, each large mass of cloud cast a shadow, thereby increasing the number of tints and beauty of the scene"

It is well to remember, in considering the subject of clouds, that there is this wonderful wealth of scenery in cloud-land, since we are too apt to judge from the view we obtain from our distant and ill placed station on the earth, and so to form altogether inadequate conceptions of the real configuration of the great cloud masses

This remembered we may proceed to consider the classification of clouds acccording to the different modifications commonly observable.

The classification now generally recognised is that which Luke Howard proposed in 1803 He divided clouds into seven orders, three of these were simple, viz —The *Cirrus*, the *Cumulus*, and the *Stratus*; and four compound or intermediates, viz —The *Cirro Cumulus*, *Cirro-Stratus*, the *Cumulo-Stratus*, and the *Cumulo-Cirro-Stratus* or *Nimbus*.

Cirrus Cloud.—This cloud consists of wavy thin filaments, parallel or diverging It is lighter than any other form of cloud, and appears at a greater elevation It is probable that the particles of this cloud are ice-crystals Sometimes the Cirrus cloud presents the appearance of a delicate net-work, at others it resembles woolly hair, horse tails, &c It commonly appears either motionless or to move very slowly, but in reality this appearance is due only to the great distance at which this form of cloud usually lies In balloon ascents, even those in which the greatest altitudes have been reached, cirrus clouds have been seen at an enormous height above the observer

Cumulus Cloud —This name is given to clouds of a hemispherical form, with horizontal base, which commonly appear in early morning, and chiefly in summer, so that they have been called *summer clouds* and *day clouds* They are formed much nearer to the earth than the Cirrus clouds Tyndall thus describes the mode of their formation —"The warmed air, charged with vapour, rises in columns, so as to penetrate the vapour screen which hugs the earth, in the presence of space, the head of each pillar wastes its heat by radiation, condenses to a cumulus, which constitutes the visible capital of an invisible column of suspended air" Saussure ascribes their shape to the way in which they are formed, comparing the progress of the column of invisible vapour through the surrounding air to the motion of one fluid through another But it seems more consistent with the observed appearance and changes of appearance of the cumulus clouds, to suppose that their bulbous form above is due to the expansion of the air where the invisible vapour has condensed That condensation must be accompanied with the discharge of large quantities of heat, and the movements of the cumulus corresponds exactly with the effects we should ascribe to the sudden dilation of the air resulting from this access of heat

Stratus —This name is given to a widely extended sheet of cloud forming a continuous layer It lies at a lower level than the cumulus, its lower surface often resting on the earth It has been called the *Cloud of Night*, because it generally forms about sunset, and commonly grows denser during the night It is due to the mass of vapour which has been raised by the sun's heat during the day This vapour sinks slowly down towards evening, and as at this part of the day the air is colder near the earth, the descending vapour, at first invisible, slowly condenses near the earth As the process continues, condensation takes place at higher and higher levels Sometimes the upper level of the stratus is so well defined, that the gradual increase of the cloud produces an appearance resembling the effects of an inundation The breaking up of the Stratus cloud in the morning is a process of a different character The Stratus does not slowly sink as it had risen, but as the sun shines upon its upper surface, ascending streams of aqueous vapour begin to be produced, which quickly lead to the formation of rounded masses of cumulus, and the stratus is finally broken up altogether into cumulus clouds

Cirro Cumulus —A cloud resulting from the breaking up of the Cirrus cloud into round masses, the whole slowly sinking, though not to the ordinary level of the Cumulus cloud

Cirro-Stratus —A cloud consisting of horizontal or slightly inclined flakes, thinned off at the edges The forms are very variable, but the cloud may always be known by this peculiarity of structure

Cumulo Stratus —A cloud formed by the Cirro Stratus mixing with the Cumulus, "either among its piled up heaps or spreading underneath its base as a horizonal layer of vapour" Buchan in his excellent "Handy-Book of Meteorology," adds that the *distinct* Cumulo-Stratus "is formed when the Cumulus becomes surrounded with small fleecy clouds just before rain begins to fall, and also on the approach of thunder storms" Tennyson has finely described this form of cloud

"That rises upward always higher
And onward drags a labouring breast,
And topples round the dreary west
A looming bastion fringed with fire"

Cumulo-Cirro-Stratus, or *Nimbus* —The well-known rain cloud Its formation is the result of the super-saturation of the space between Cirro Stratus clouds and a lower layer of Cumulus clouds The two layers thus rapidly increase, and eventually unite From the mass thus formed, rain soon begins to fall

The observation of clouds now forms a regular part of the work of a meteorological observatory, and, therefore, the nomenclature above explained subserves a useful purpose in enabling observers to record the varying aspect of the heavens It requires extension, however, so as to include other forms of cloud which are not directly referable to any of the above forms.

COATING OF A LEYDEN JAR OR CONDENSER. The tinfoil coverings pasted upon the inside and outside of a Leyden jar, or on the two sides of a condenser such as the Fulminating Pane, are called the *coatings*. (See *Leyden Jar*.) Even when instead of tinfoil, as is the case in some electrometers and pieces of apparatus for particular experiments, a liquid conductor is used within or without the jar instead of the tinfoil, still the surface of the liquid next to the glass, or other non conductor, is called the *coating*, since it performs the same office as the metal.

COBALT. A metallic element first isolated by Brandt in 1733, although compounds of it were known to the ancients. Symbol Co. Atomic weight 58.5. It is a hard, steel gray metal which takes a good polish, fuses at about the same temperature as iron, is magnetic, although not so powerfully so as iron, and oxidises at a red heat. Mineral acids dissolve it, forming salts. The following are the principal compounds of cobalt—

Protoxide of Cobalt (CoO.) In the anhydrous state this is a light greenish gray powder, and when hydrated a dirty rose-coloured powder. It dissolves in acids to form salts.

Chloride of Cobalt ($CoCl_2$) forms in the hydrated state pink crystals, which become blue when anhydrous. It is soluble in water.

Cobalt is frequently associated with nickel in its ores, and its separation from this metal is a matter of some difficulty, and can only be effected in the wet way, *i.e.*, by solution and precipitation, &c. Cobalt forms rich blue compounds when its oxide, &c., are melted with borax, glass, enamel, porcelain glaze, &c., and on this account it is largely used in the arts.

COEFFICIENT OF DISPERSION. See *Dispersion, Coefficient of*.

COEFFICIENT OF EXPANSION. See *Expansion*.

COEFFICIENT OF FRICTION. See *Friction*.

CŒLESTIN. See *Sulphates, Strontium*.

COERCITIVE FORCE. A name used to designate that which makes the difference between hard steel and soft iron in taking on and in retaining magnetic polarisation. Thus it is found that, under the influence of a magnet, a soft iron mass readily becomes inductively magnetised, and retains this magnetisation as long as the influencing body is present. But as soon as it is removed, the magnetisation of the soft iron ceases. Hard steel, on the other hand, is with difficulty magnetised inductively; but when once it has been forced into the polarised state, as by prolonged contact with a powerful magnet, by rubbing with a magnet or by any other means, it obstinately retains this state, and with a persistence depending upon its hardness and its molecular condition in general. Again, if soft iron, while under the influence of a powerful magnet, be hammered, twisted, or otherwise strained, it is found to retain magnetism also to an extent depending on the amount of straining and permanent contortion of molecular arrangement which it has undergone. The hammering has thus, by altering the molecular arrangement, conferred upon the bar a force which acts so as to maintain the magnetic polarised state in it. It is to this that the name *coercitive force* is given. (See also *Magnet*.)

COHESION. (*Cohæreo*, pret. *cohæsi*, to stick together.) The force by which the particles of bodies unite and remain in contact so as to form one mass. It is one of the molecular forces acting at inappreciable distances, and is thus distinguished from gravitation. It unites the particles of the same kind of matter, and is thus distinguished from adhesion, or the force which unites the particles of different substances, and from chemical attraction, or the force which unites the particles of different substances, so as to form substances having properties differing from those of their components. The force of cohesion in bodies is measured by the force necessary to pull them asunder, or separate them by crushing. Cohesion is most powerful amongst the molecules of solids, almost absent amongst those of liquids, and entirely absent in gases. Hardness, softness, tenacity, elasticity, malleability, and ductility are modifications of cohesion. (See these terms.) Cohesion in almost all cases is overcome by *heat*.

COHESION OF LIQUIDS. Though the cohesion between the neighbouring parts of a liquid is not sufficient to maintain the shape of the liquid when acted on by any considerable mechanical force, and though even the force of resistance, exercised by the bottom and walls of a vessel into which a liquid is poured, which force is called into existence, causes the liquid to assume the shape of the vessel in which it is placed, and present a horizontal surface, yet liquids have appreciable and measureable cohesion. This is shown by the spherical form assumed by masses of liquids removed as far as possible from the influence of external forces. Of all solids a sphere satisfies most perfectly the condition that the effort of each particle towards the centre of gravity is most gratified. When a sphere is altered in shape there must be on the whole a mean separation of particles (not contiguous ones.) Accordingly the cohesion determines the spherical form. Although it is impossible to withdraw a liquid mass from all external forces, notably from gravitation, yet the action of gravity may be completely and symmetrically counteracted by immersing a liquid mass in another liquid, having precisely the

same specific gravity as the first, but being immiscible with it. Thus, if olive oil be poured into a mixture of alcohol and water of a certain strength, and therefore specific gravity—namely, that of the oil (about 0·915), the oil will be pressed on all sides by equal forces, these may therefore be considered as having no influence in determining the shape of the oil. The latter assumes the shape of a perfect sphere in consequence of its cohesion. In truth, assisted by the cohesion of the water which, in gratifying its cohesion to the utmost, will leave a spherical cavity. Forms approaching the spherical are also assumed by small liquid masses when they rest on surfaces between which and themselves there is less adhesion than the cohesion they themselves possess. This is seen when a dewdrop rests upon a resinous leaf, or is supported above the leaf by fine hairs, when a water drop rests upon a plate of wax or fat, on a surface covered with resinous dust, or a drop of mercury on any non metallic surface. A drop of water may rest upon a surface of water without immediately mixing therewith, being separated therefrom by a film of air, or it may rest above a surface of metal if the latter is sufficiently hot for its radiant heat to cause sufficient evaporation from the drop to interpose a coating of vapour between the two. (See *Leidenfrost's Experiment*.) In all such cases the drop assumes more or less of a spherical form. Direct experiments for determining the cohesion of liquids were made by Gay-Lussac. His method was based upon the fact that when a solid, which is wetted by a liquid, is withdrawn from it, the latter must be ruptured, so that the force required to effect the separation is a measure of the cohesion of the liquid, and not of the adhesion between the solid and liquid, provided that such adhesion is greater than the liquid's cohesion, which is the case when the solid is wetted. A flat circular disk was hung horizontally from one pan of a balance, and exactly counterpoised. The surfaces of liquids in basins were brought into contact with this disk, and weights were put upon the opposite pan until the plate was torn away from the liquid. If the force required in the case of water be called 1·0, it was found to be 0·574 for turpentine, and in that of absolute alcohol 0·523, and on examining mixtures of alcohol and water it was found that the cohesion increased with the quantity of water. A more exact method of measuring the cohesion of liquids is based upon the determination of the size of drops which they form under like conditions. (See *Drops*.)

COHESION FIGURES OF LIQUIDS. A peculiar phenomenon resulting from the joint action of adhesion and cohesion in certain liquids when one is added to the other. Although many liquids mix completely with one another in almost any proportions, or dissolve each other freely, yet there are others which may form saturated solutions, so that any increase in quantity of the saturating liquid is not incorporated with the rest. Its particles cohere and arrange themselves, with respect to the solution, according to their specific gravity. Thus the most limpid ethers and oils will only dissolve to a small extent in water, the greater part of them collecting together again after being shaken with water; while more viscous liquids, as common oils, do not appear to dissolve in water at all. If a drop of chloroform be let fall in water, it retains its circular form; a slight amount of alkaline liquid added to the water causes the drops to become flattened, but the rounded form is once more assumed when the alkali is neutralised by a little acid.

Many of the substances thus slightly soluble in water form characteristic figures when drops of them are lightly added to pure water in a perfectly clean vessel. The tendency to adhesion between the liquids causes the drop to assume at first a flattened form, but the cohesion of the particles breaks up the film in various directions, so as to constitute characteristic patterns on the surface of the water. The constant alternation of predominance between adhesion and cohesion proceeds, the smaller portions being flattened by adhesion, and then further subdivided by cohesion, until finally a definite outline is produced. The figure, however, passes away in a space of time proportional to its insolubility in water. The creosote figure remains for five minutes, while those of liquids which are much more soluble, such as alcohol or ether, last less than a second. Creosote forms a disk which sails about on the surface with a rapidly quivering edge. Ether forms a circular figure, composed of a central boss, surrounded first by a flat depressed ring, and then by a raised ring, the edge of which is waved. The essential oil of lavender forms a film with iridescent rings covering a large part of the surface; the film then breaks up into small disks, first passing through a complicated pattern like that of Carrageen moss. Mr Tomlinson produces these figures in shallow glass vessels $3\frac{1}{2}$ inches in diameter, made chemically clean by means of sulphuric acid, alcohol, alkaline solutions, and abundant rinsing. The figures vary with the nature of the liquid surface on which the drops are spread, as when, instead of water, the surfaces of cocoa nut oil, castor oil, melted paraffin, wax, &c., are used. (See *Phil. Mag.*, November 1864.) When the drops, instead of spreading on the surface, sink below it, a new set of figures is formed, for which see *Submersion Figures*. These figures are not only serviceable for the recognition of the substances themselves, but also for the detection of adulterations of them by other oily or slightly soluble liquids. For when a mixed liquid

is dropped upon water in the manner above described, its cohesion figure partakes of the characters of each constituent when used separately such is the case, for instance, with a mixture of turpentine and an essential oil Mr Tomlinson's extended researches on this subject will be found in the Philosophical Magazine, Oct 1861, and March 1862

COIL, PRIMARY AND SECONDARY Terms used respecting apparatus employed for current induction The wire which transmits the current from the battery—that is, the inducing wire—is called the *primary coil* The *secondary coil* is the circuit which the induced current traverses The primary coil is made of pretty thick wire, and not very long, in order that the current from the battery may not be too much weakened by resistance The secondary coil, on the contrary, is made of the finest possible wire, and of great length, in order that a very large number of turns of it may be brought under the influence of the primary coil The advantage gained by increasing the number of turns, and getting them near to the coil in which the current is passing, far more than counterbalances the disadvantages arising from increasing the resistance It is necessary that the several turns of the secondary coil should be very carefully insulated from each other, for the induced electricity will otherwise leap across, instead of passing round each turn of the wire For this reason the wire, as it is coiled on, is covered with the layers of shell-lac or gutta percha

COINING-PRESS An instrument for stamping coins It usually consists of a steel die bearing the impression to be stamped, fixed into a vertical screw, and of two heavy balls of metal at the extremities of a lever, with equal arms at right angles to the screw The balls are turned round very rapidly several times, and then left free The die is thus driven down upon the coin, and the accumulated momentum of the large moving mass is expended in impressing the required figure

COLD (Anglo-Saxon, *ceald*, from *colian*, to cool) It was formerly believed that cold was an entity, and that it could be reflected from polished surface like heat and light This, however, is not the case Cold is simply an absence of heat It is essentially a relative term Ice may be considered a hot substance when compared with frozen mercury, and a very hot substance when compared with solid carbonic acid If we take three vessels and pour hot water into the first cold water into the second, and water of intermediate temperature into the third, and place one hand in the hot water, and the other in the cold, we shall find, on now placing both hands in the water of intermediate temperature, it will feel hot to the hand which has been in the cold water, and cold to the hand which has been in the hot water Thus, water at one temperature may appear both hot and cold Absolute cold would be the absolute zero of temperature, at which point matter would possess no heat at all A substance is relatively cold when it possesses less of the motion called heat than the substance it is compared with A hot substance, a red-hot suspended ball of metal, for instance, gets colder and colder, because it radiates its heat into space, it loses molecular motion, and the more motion it loses the colder it is said to be When it cools down to a temperature below that of our bodies, we call it cold to the touch, because it possesses less of the motion of heat than our nerves, and abstracts heat from them, and this withdrawal of motion from the nerves produces the sensation of cold

COLLIMATION, LINE OF A term used in reference to telescopes, to designate the line passing through the axis of the object-glass, and the intersection of the cross-wires in the focus of the eye-piece

COLLIMATOR (*Collimo*, to aim) An instrument chiefly used in connection with transit observations for securing the axis of the telescope pointing in the right horizontal direction It generally consists of a small subsidiary telescope with cross wires in the focus of its eye-piece, fixed at some distance from the principal telescope, and pointing towards it When the transit telescope is directed horizontally it looks into the object glass of the collimating telescope, and renders visible the cross wires in the focus of the latter If the image of these wires coincides with the image of the cross wires of the large telescope, it shows that the line of collimation is true A collimator is usually fixed opposite each end of a transit instrument A collimator is also frequently used in optical instruments, in the spectroscope, for instance, it consists of a convex lens, having the slit in its principal focus (See *Spectroscope*)

COLLODION PROCESS A process in photography by which negative representations of natural objects are taken by means of a camera obscura on a plate of glass The principle of the process is as follows —The soluble form of gun cotton is dissolved in a mixture of alcohol and ether and a metallic iodide (or in some cases a bromide) added When this mixture is poured upon a plate of glass, and the excess drained off, the ether and much of the alcohol evaporate, and leave a thin collodion film, like a skin on the glass Before this has got quite dry it is dipped into a bath of nitrate of silver, which, reacting on the iodide present, precipitates iodide of silver in an extremely fine state of division in the pores of the film The plate is now exposed in a moist condition to the image in the camera, and the latent image is after-

wards developed by pouring over it a reducing agent, such as sulphate of iron or pyrogallic acid This causes the invisible image to make its appearance, those parts of the iodide of silver film, upon which the light has shone, attract to themselves molecules of metallic silver, ready to precipitate from the supernatant liquid, and, in the course of a few minutes, the picture has fully appeared, with the light and shade reversed, but perfect in gradation of tint The unaffected iodide of silver is lastly dissolved off by means of hyposulphite of sodium, or cyanide of potassium, and the picture is washed, dried, and varnished From a negative of this kind hundreds of positives may be printed, having the light and shade as in nature. (See *Photography*)

COLLOID (*Collegelatine*) See *Dialysis*

COLOUR BLINDNESS An infirmity of the human eye, by which it is unable to distinguish certain colours It is frequently known as *Daltonism*, from the chemist Dalton, who laboured under this disease The eye, in most instances, is sensitive to even faint light, and distinguishes perfectly the form of bodies, but different colours, such as red and green, cannot be distinguished from one another, thus ripe cherries cannot sometimes be distinguished in colour from the leaves by which they are surrounded In this case, looking through a red glass would show the difference Daltonism is not an uncommon infirmity, and it should always be specially looked for when men are engaged in work which depends on appreciation of colour Railway accidents, for instance, may occasionally have happened owing to the driver being unable to distinguish a red from a green signal

COLOURED FLAMES When certain metallic compounds are introduced into a non-luminous flame, such as the flame of a spirit lamp, or a Bunsen gas flame, characteristic colours are produced The following is a list of the principal coloured flames, with the substances producing them —

BLUE FLAMES	
Intense blue,	Chloride of copper.
Pale clear blue,	Lead
Light blue,	Arsenic
Blue,	Selenium
Greenish blue,	Antimony
Blue mixed with green,	Bromide of copper.
GREEN FLAMES	
Intense emerald green,	Thallium
Dark green,	Boracic acid
Full green,	Tellurium or copper.
Emerald green mixed with blue,	Iodide of copper
Pale green,	Phosphoric acid.
Apple green,	Barium
Intense whitish green	Zinc
Bluish green,	Binoxide of tin.
YELLOW FLAME	
Intense yellow,	Sodium.
RED FLAMES	
Intense crimson,	Lithium
Red,	Strontium
Reddish purple,	Calcium
Violet,	Potassium

These observations are best made in a dark room, and with a small flame Very beautiful spectrum phenomena are observable when some of these coloured flames are examined in the spectroscope (See *Spectrum*, *Spectroscope*)

COLOURED RINGS See *Newton's Rings.*

COLOURED SHADOWS. When a coloured light (red for instance) and a white one throw the shadow of the same object upon a white surface, that thrown by the interception of the white light will look red, as the red is the only light shining on that part of the surface But the shadow thrown by the red light will look *green* This is caused by the retina being somewhat deadened to red light, owing to the great surface illuminated by this colour, and therefore causing the small portion, from which the red light is intercepted, to appear green, the complementary colour to red. A similar effect is seen at night when a double shadow of a person is thrown on the pavement by the moon and a gas lamp.

COLOURED STARS, SPECTRA OF The spectra of stars which present a decided

olour are generally seen to have some portions thickly covered with black lines, whilst other portions are comparatively free from black lines Thus, in β Cygni, there are two stars close together, one orange, the other blue The orange star gives a spectrum in which the dark lines are almost entirely confined to the blue and violet end, whilst the spectrum of the blue star is thickly covered with dark lines in the red and orange portion (See *Stars, Spectra of*)

COLOUR OF TONE The ear can distinguish a difference between two notes which are of the same pitch and the same loudness, if they are produced by instruments of different kinds, as a flute and a violin The difference, which is familiar to all, can scarcely be described, nor its rationale properly understood When a stretched string is plucked, it is seen scarcely ever to move in a plane, but its parts describe elliptic spirals, the axes of which revolve or oscillate The first impulse given to the air by such a string must also, therefore, be spirally applied In the case of the flute which sounds by reason of simple compression and rarefaction of the air, no such spiral impulse is given It can scarcely, however, be allowed that the complex motion given by the string should preserve its complexity in the travelling wave It is more probable that the difference of colour is due to the existence of feebly sounding harmonics When a string is plucked or struck at its centre it will vibrate as a whole, giving the fundamental note, it will also, and at the same time, vibrate in two segments, each giving rise to the higher octave If the point plucked or struck be not the central one, an indefinite number of harmonic and other notes may be produced The "richness" of a note seems to depend upon the number of these secondary sounds upon their harmonizing with and being in subordination to the fundamental note This relation obtains in the gong, and to a certain extent in the cymbal A note to which the expression "twang" or "clang" is applied always includes several secondary notes

COLOURS, ABSORPTION OF No transparent substance allows all colours to pass through with equal facility, except, perhaps, when it is reduced to excessive thinness Many substances, such as coloured glasses, are almost opaque to some parts of the spectrum, whilst they allow other colours to pass through readily Many metallic solutions, when examined by means of the spectroscope, are seen to absorb different colours in very definite parts of the spectrum, forming absorption bands or lines, varying in width and intensity according to the strength of the solution A great many organic colouring matters likewise possess this property For further particulars, see Papers by Professor Stokes (Chem Soc Jour xvii, p 304), and by Dr J H Gladstone (Chem Soc Jour x, p 79) See *Absorption of Light*

COLOURS, COMPLEMENTARY See *Complementary Colours*

COLOURS, COMPOSITION OF The pure colours of the solar spectrum are called simple colours, by causing two or more of these to mix together compound colours are produced A compound colour is sometimes similar in the effect it produces on the eye to a simple colour, but more frequently it is different to any in the spectrum Of this class are pink, brown, &c

COLOURS, NEWTON'S SCALE OF See *Newton's Scale of Colours*

COLOURS OF BODIES The colour of natural bodies is, in most cases, due to their absorbing some colours and reflecting others They appear to be of the colour which they reflect back to the eye Some colours, however, such as those on butterflies' wings, the feathers of some birds, the wing cases of insects, opals, mother-of pearl, &c, are due to the decomposition of light by reflection from *grooved surfaces*, or *thin plates* (which see) The colours of bodies depend upon the kind of light by which they are illuminated thus by a yellow soda flame, all substances appear either yellow or black Bodies also vary in colour according to the mechanical state of division in which they occur This is clearly exemplified in the beautiful phenomena of blue and ruby gold, investigated by Faraday (See *Gold, Relation of, to Light*) Gold in thin plates reflects yellow and transmits green light, but when suspended, in a very fine state of division, in water, it transmits blue, purple, or ruby light, according to the state of division in which it is precipitated These solutions all contain metallic gold in suspension, as Faraday has most conclusively shown, and yet they transmit totally different rays Dr Roscoe has adduced several instances of similar change of colour, which he considers to be due to minute division (See *Proceedings of the Royal Institution*, June 1, 1866) He considers that the varying size of the reflecting particles in the atmosphere (dust, aqueous vapour, germs, &c), may aid in producing the widely differing sunset tints, from deep ruby red to yellow, and even blue, for there are several well-authenticated cases in which the sun has been seen to be blue. Thus, in the year 1831, a blue sun was noticed over a great part of Europe, and also in America (See *Opalescence of the Atmosphere*) The light transmitted by finely divided sulphur is red, blue sulphur can, however, be formed Thus, if we add sesquichloride of iron to solution of sulphuretted hydrogen, we get a transient but very splendid purple tint, and it is probable that this is due to the size of the particles of sulphur precipitated. If we heat sulphuretted hydro-

gen water up to 200° C, the gas decomposes, with separation of sulphur, and the solution attains a deep blue colour. On cooling, the colour disappears, sulphur is deposited, and the liquid becomes milky. Again, if we dissolve sulphur in anhydrous sulphuric acid, a magnificent deep blue colour is obtained, although no chemical action that we know of occurs. When the analogues of sulphur, selenium, and tellurium, are acted upon by anhydrous sulphuric acid, they also yield magnificently coloured liquids, selenium giving a deep olive green solution, and tellurium a brilliant ruby red colour. The ruby red gold liquid is as transparent, and apparently as truly a liquid as the red solution of tellurium, yet we know that finely suspended metallic gold is the cause of this red tint. Dr Roscoe, therefore, asks whether it is contrary to analogy to suppose that the colour of this red liquid is caused by the particles of finely divided tellurium, or that of these blue and green liquids by the particles of sulphur and selenium. (See *Absorption of Light*)

COLOURS OF FILMS. See *Thin Plates, Colours of*

COLOURS OF GROOVED SURFACES. See *Grooved Surfaces, Colours of*

COLOURS OF METALS. See *Metals, Colours of*

COLOURS OF SALTS IN SOLUTION. Dr J H Gladstone has supplied us with nearly all the knowledge which we possess on the rays of the spectrum which coloured salts absorb. The general law appears to be this:—A particular base or acid has the same effect on the rays of light with whatever it may be combined in aqueous solution. Hence it may be inferred that when two bodies combine, each of which has a different influence on the rays of light, a solution of the salt itself will transmit only those rays which are not absorbed by either, or, in other words, those which are transmitted by both. (Phil Mag, Dec 1857.) The method of examination recommended by Gladstone is briefly as follows:—The solution to be examined is placed in a hollow wedge of glass, which is interposed between the eye of the spectator and a narrow slit in the window shutter, in such a manner that the thin line of light is seen traversing the different thicknesses of liquid. This line of light is then analysed by placing a good prism between the hollow wedge and the eye. In this way it is seen at once what rays are absorbed by increasing thicknesses of solution. The results given by Dr Gladstone show that each coloured constituent of a salt retains its specific absorbent power when in combination. Three cases, however, which he gives are anomalous, namely, the chromate of chromium, the double iodide of platinum and potassium, and the ferric ferrocyanide dissolved in oxalic acid. This latter transmits blue rays in great abundance, which are absorbed both by ordinary ferrocyanides and by ferric salts.

The effect of heat on the colour of salts in solution has also been examined by Gladstone. As a general rule the solution of a salt has the same power of absorbing or transmitting the rays of light at all temperatures. Nevertheless it is not rare to find coloured salts which when dissolved in water vary in shade or in tint according to the temperature. In the following instances heating the solution seems merely to intensify the colour:

Meconate of iron—red
Ter-bromide of gold—red
Pernitrate of cerium—red
Bichromate of potash—orange
Ferrocyanide of potassium—yellow
Molybdous chloride—green

In the following cases a change takes place in the character as well as in the intensity of the colour when the solution is heated, it being understood that the change of colour lasts only as long as the heat continues, no permanent chemical change being effected, and the original colour of the solution returns in every instance as it cools.

Bichloride of platinum, while it becomes more intense in colour, assumes also a redder tint. Protochloride of platinum dissolved in hydrochloric acid behaves in the same way. Bichloride of palladium acts similarly. Ferrocyanide of potassium gives a greenish solution, which when heated alters in colour, and if not too dilute assumes a distinctly red appearance. Polysulphide of potassium passes from yellow to a most intense red. Sesquichloride of iron passes from yellow to a most intense red. Chloride of nickel passes from a bluish to a yellowish green. Iodide of nickel when dissolved in a little water gives a clear green solution, which on the application of heat becomes of a nondescript shade that appears distinctly red by gaslight. Chloride of copper gives a green saturated solution which on the addition of more water becomes blue. If this blue solution be heated (unless too dilute) the green colour is restored. Bromide of copper behaves like the chloride. Sulphocyanide of cobalt in a minimum of water gives a magnificent bluish purple colour, but on dilution it changes to the ordinary pink tint of cobalt salts in solution. If this be heated, provided it is not too dilute, it will reassume the purple hue. Chloride of cobalt dissolves in water always of a pink, and in absolute alcohol always of

a blue colour, while in mixtures of alcohol and water it will assume an intermediate tint By arranging properly the proportions of the two solvents a liquid may be obtained which will show all the changes of an aqueous solution of the sulphocyanide passing from pink through purple to blue when it is heated, and conversely from blue to pink when it is cooled (See *Absorption of Light*)

COLOURS OF THICK PLATES See *Thick Plates, Colours of*

COLOURS OF THIN PLATES See *Thin Plates, Colours of*

COLOURS PRODUCED BY POLARISATION When a thin film of a doubly refracting crystal is viewed in the polariscope, very brilliant colours are produced, depending upon the thickness of the film, and the angles which the polariser, analyser, and crystalline film form with each other The cause of the production of colour is briefly as follows The light passing through the polariser, is doubly refracted by the crystalline plate, but, as this is excessively thin, the ordinary and the extraordinary ray, which pass through with different velocities, emerge superposed, and the vibrations consequently interfere with one another, producing colour As, however, the colour produced by one set of waves is complementary to that produced by the other set of waves, nothing but white light is seen The analyser here comes into play, this resolves the two sets of rays each into two other systems, two vibrating in one plane, and the other two in another plane The vibrations in each plane interfere and produce colour, and these being in opposite states of vibration, the analyser is able to suppress one and transmit the other, and thus render the colour visible The interfering vibrations in one plane strengthen each other, whilst those of the opposite plane oppose each other, and the result is that the colour produced by interference, in one case, is complementary to that produced in the other case By rotating the analyser, these two colours are alternately transmitted, passing through an intermediate neutral point of white light The best crystal for showing colours is selenite, as it splits very easily into films of the requisite thickness If, instead of selenite, a slice of a uniaxial crystal, such as calcspar, is examined in the polariscope, the amount of double refraction varies according to the angle which the light forms with the optic axis, and the varying interference thereby produced causes the production of coloured rings around a black cross If the crystal has two axes, the figure is somewhat elliptical around a black cross, which on rotation changes into two black hyperbolic curves (See *Polarised Light, Polariscope*)

COLUMBA (Abbreviated from *Columba Noachi*, Noah's Dove) A small southern constellation formed by Royer It comprises a somewhat rich group of small stars

COLUMBIUM An excessively rare metallic element, discovered by Hatchett in 1801, in a mineral called columbite Subsequently Wollaston pronounced Columbium to be the same as Ekeberg's tantalum In 1846 H Rose was led to conclude that columbite contained two metals closely resembling tantalum but not identical with it, to these he gave the names pelopium and niobium He has since found that niobium and pelopium are the same metal, and he therefore discarded the name pelopium and retained niobium But this niobium is the same as Hatchett's columbium, and, therefore, it is only right that it should be recognised by the name given to it by the original discoverer This alteration of name is now gradually coming into use, and chemists will, it is hoped, recognise columbium and tantalum as the two metals which have been vaguely known under the names tantalum, niobium, pelopium, and columbium

COLUMN, ELECTRIC Another name for Volta's Pile (which see) It is called an electric column from its form, consisting, as it does, of a pillar composed of a very large number of copper, zinc, and moistened flannel discs piled one above the other alternately

COLURE (κόλουρος, curtailed, imperfect) In astronomy, a colure is a great circle of the sphere passing through the poles of the heavens, and the equinoctial points and solstitial points on the ecliptic The circle through the equinoctial points is called the *equinoctial colure*, that through the solstitial points, the *solstitial colure* A part of these circles is at all times beneath the horizon, hence (it is supposed), their being named colures

COMA (Abbreviated from *Coma Berenices*, Berenice's Hair) One of Ptolemy's northern constellations Doubtless this star-group originally belonged to the constellation Leo It consists of a somewhat widely dispersed cluster of small stars Sir William Herschel considered this group as the nearest of the system of nebulæ which occupies the region covered by the constellation, a theory which is not clearly intelligible when we remember that some of the stars forming the constellation are of the fourth magnitude, and would therefore seem to belong beyond question to the sidereal system, not to be the components of an external galaxy

COMBINATION, CHEMICAL See *Affinity, Atomic Theory*

COMBINATION, HEAT OF See *Heat of Combination*

COMBUSTION (*Comburo, Combustus*, to consume) When substances combine chemically, and the combination is attended by the evolution of light and heat, the phenomenon is called

combustion All ordinary combustion is the union of an inflammable body with oxygen gas, the most familiar example of which is found in the burning of coal in a fireplace As other forms of combustion, we have metals burning in chlorine, or the vapour of bromine Substances, like oxygen, which combine with inflammable bodies attended by the phenomenon of combustion, are called *supporters of combustion*, while the substances burnt, such as coal, are called *combustibles* The term *slow combustion*, which is sometimes used in such cases as the gradual oxidation of moist phosphorus, is very inappropriate, and should always be replaced by *slow oxidation*, or *slow chemical union*, because combustion is a more or less violent action, accompanied by the production of intense light and heat When carbon is burnt in oxygen gas, we have an example of combustion, but when the electric arc passes between two carbon points placed in a vacuum, we have an example of *ignition* According to a theory, which has received considerable support, the heat produced during chemical combination is caused by the direct conversion of motion into heat (See *Heat*, *Mechanical Equivalent of Heat*) Thus, the combustion of carbon in oxygen, is said to be due to the clashing of carbon and oxygen atoms, which rush together under the influence of the force of chemical affinity with an enormous velocity, and when they come into collision their motion of translation is transmuted into that kind of vibratory motion which we call heat

COMES (A Companion) A name sometimes given by astronomers to the smaller star of a very unequal pair

COMET (κομήτης, long haired) The name given by astronomers to a class of celestial objects presenting a nebulous aspect, but traversing the interstellar spaces, and becoming known to us by passing within the limits of the sun's attraction Many of them belong to the solar system, travelling in closed paths around the sun

Although the idea that comets may travel in periodic orbits around the sun had suggested itself to the ancients, and was even said to have been definitely taught by the ancient Chaldean astronomers, we owe to Newton the first enunciation of this theory He founded it upon the calculations he had applied to the motions of the great comet of 1680 The theory can hardly be said to have been proved, however, until the time of Halley's researches into the motions and periodic returns of the comet which bears his name, or perhaps even until the date of the first return of this comet in accordance with Halley's predictions

A comet usually presents the appearance of a *coma*, or haze of light surrounding a somewhat bright nucleus As the comet approaches the sun the haze of light generally grows elongated, and when the comet is a large one, traces begin to be seen which indicate the approaching formation of a *tail* A certain appearance of streakiness in the comet's light usually precedes the formation of the tail The direction of the tail is nearly always from the sun It grows longer and brighter as the comet approaches perihelion After perihelion passage many comets are greatly changed in appearance Some are brighter and more striking than they were before perihelion passage, while others are shorn of a large proportion of their splendour The latter was the case with the comet of 1835-36, as we learn from Sir J. Herschel who observed it in the southern heavens after it had passed away from our skies On the contrary, the comet of 1811 appeared in its full splendour after perihelion passage

The only feature which belongs to *all* comets is the coma Many comets have no nucleus, and quite a large proportion have no tail, on the other hand, some comets have more than one tail One appeared in 1744 which had no less than six tails, symmetrically disposed in the figure of a half opened, but somewhat curved fan Others have exhibited a yet more anomalous appearance, having, besides a tail in the usual position, a second abnormal tail, inclined to the first at a considerable angle Sometimes the tail seems completely separated from the head by a dark gap, more commonly, however, there is a dark space immediately behind the head, but on each side of this space the light from the head is continued so as to form a bright border on each side of the tail

The real dimensions of comets must, in many cases, be regarded as inconceivably vast, many times larger, for example, than the combined volume of the sun and all the orbs which circle round him On the other hand, comets are bodies of small mass, their attractions not appearing to have any influence even on the smallest bodies belonging to the solar system

The particulars in the three following paragraphs are taken from the excellent appendix which Mr Dunkin, of the Greenwich Observatory, has added to Lardner's Handbook of Astronomy

Distribution of the Cometary Orbits in space Although the cometary orbits exhibit every variety of figure and position, while some comets travel in a retrograde, others in a direct manner around the sun, yet there are not wanting signs of law, even in the distribution of the paths followed by these seemingly most erratic bodies In the first place as regards the inclination of the cometary orbits, there are signs of a tendency among the planes of these orbits to

collect themselves as tangent planes to an imaginary cone, having the sun as its vertex, its axis at right angles to the plane of the ecliptic, and having a half vertical angle of about 45 degrees. As regards the distribution of the cometic perihelia, there seems to be a well-marked tendency to a great increase in the sun's neighbourhood. The following table indicates the proportional number of perihelia found between given limits of distance, and the deduced richness of distribution of perihelia, the column headed cubical space referring to the actual volume of spherical shells centrally placed round the sun, and having their bounding surfaces at the distances from him which are indicated in the first column —

Limiting Distances from Sun in millions of miles	Number of Perihelia	Cubical Space	Density of Perihelia
0 to 20	8 65	1	8 65
20 to 40	11 70	7	1 67
40 to 60	20 30	19	1 06
60 to 80	17 20	37	0 47
80 to 100	20 80	61	0 34
100 to 120	8 65	91	0 095

It is impossible not to recognise in the relations here presented the existence of a well-marked law of increase towards the sun's neighbourhood. This increase is the more remarkable, because all comets whose orbits lie wholly within the earth must escape recognition. One can hardly doubt that many such bodies exist. If so, the number of perihelia within the earth's orbit may increase in a very much greater proportion than that indicated in the above table.

General Laws affecting Cometic Orbital Motions. Although the comets present so many remarkable features of diversity from all the other members of the solar family, yet the diversity is less marked in some cometic groups than in others. For example, the orbits of the comets which travel within the path of Saturn are characterised by a tendency to exhibit what may be termed planetary features. Many of them are, indeed, inclined to the plane of the ecliptic at considerable angles, yet they show a decided general preference for that plane. In this respect, indeed, they closely resemble the asteroids, but their eccentricity is in every instance greater than in any case of asteroidal motion. The following table indicates these relations unmistakably —

Name of Comet.	Mean distance from Sun	Eccentricity	Inclination	Period in years
Encke's	2 2181	0 8464	13° 4′15″	3 303
Blampain's	2 8490	0 6867	9 11 6	4 809
Burckhardt's	2 9337	0 8640	8 1 45	5 025
Clausen's	3 0913	0 7213	1 53 43	5 435
De Vico's	3 1028	0 6173	2 54 45	5 469
Winnecke's	3 1343	0 7547	10 48 4	5 549
Brorsen's	3 1463	0 7945	30 57 51	5 581
Lexell's	3 1560	0 7861	1 34 28	5 607
Pons's	3 1602	0 7552	10 42 48	5 618
D'Arrest's	3 4618	0 6609	13 56 6	6 380
Biela's	3 5306	0 7563	12 33 17	6 635
Faye's	3 8118	0 5576	11 22 7	7 414
Pigott's	4 6496	0 6784	47 43 0	10 025
Peters's	6 3206	0 7567	13 2 14	15 990

All these Comets travel in a direct manner around the sun.

Now, in considering a group of comets having mean distances considerably exceeding those of the comets in the above list, we find at once increased eccentricity, a much greater average of inclination, and no longer that uniformly direct motion which characterises the comets of short period.

Take for instance the following table, which includes six comets whose aphelia lie beyond, but not (relatively) very far beyond the orbit of Neptune.—

Name of Comet	Mean distance from Sun	Eccentricity	Inclination	Period in years
Westphal's	16 6200	0 9248	40°58′32″	67 770
Pons's	17 0955	0 9545	73 57 3	70 068
De Vico's	17 5[illegible]	0 9544	84 57 13	73 250
Olbers'	17 [illegible]38	0 9312	44 29 55	74 050
Brorsen's	17 7795	0 9726	19 8 25	74 970
Halley's	17 9875	0 9674	17 45 5	76 680

Of these the first five move in a direct, the sixth in a retrograde manner

Now, notwithstanding the fact that amongst these two groups direct motions prevail so considerably over retrograde motions, yet in taking 203 comets, whose direction has been ascertained, Mr Dunkin finds 104 which have direct, and 99 which have retrograde motion, an equality of distribution showing that, so far as all the comets not specially associated with our system are concerned, no trace exists of any law governing the direction of motion

It will be noticed of the two groups of comets dealt with in the above tables that their orbits are related in a somewhat intimate manner with the orbits of Jupiter and Saturn as respects the first group, and that of Neptune in the case of the second The aphelia of all the comets of the first group, except the last two, lie relatively not far from the orbit of Jupiter, those of the remaining two comets are in like manner associated with the orbit of Saturn, while the orbits of all the comets in the second table are associated in a similar way with the orbit of Neptune

This evidence points to the conclusion that those comets which now form part of the solar system, revolving in closed orbits around the sun, have been introduced into that system by the action of the major planets It is clear that, supposing a comet were approaching the sun from outer space, on a path which, if there were no disturbing force, would carry it close to the sun, and then away into space again *never to return*, the action of a major planet, which should happen to be close by the comet's path, might very well serve to deflect the comet into a new orbit, having an elliptical instead of a parabolic or hyperbolic figure And it is easy to see that in the majority of instances, the scene where this disturbance took place, would be near the part of the comet's new orbit which was *most curved*, in other words, would be near the aphelion of the new orbit Now if the comet's path were considerably inclined to the plane of the ecliptic, it will be obvious that in travelling on its new path the comet would only be liable to fresh disturbance when either near the scene of its introduction into the planetary scheme, or at the exactly opposite part of its path, where it would again cross the plane of the ecliptic If, as would commonly be the case, this second point did not lie near the orbit of a planet, the comet would be only liable to fresh disturbance when near the scene of its first introduction into the solar system Thus we can understand the existence of groups of comets depending on the major planets, in such a way that while the sun principally sways their movements, one or other of the major orbs is a sort of subordinate ruler which *may* be able at some future time to expel the very comet it had introduced into the solar system This is, indeed, no imaginary case, since Lexell's comet, which was forced by the attraction of Jupiter into an orbit having a mean period of about 5½ years, was again encountered by Jupiter after completing two revolutions round the sun, and sent off on an orbit which extends far out into space, even if it be not parabolic or hyperbolic in figure The comet has never been seen since

We know so little respecting the physical condition of comets that it would be hazardous to speculate at present concerning their real nature A theory of great ingenuity, and (what is novel in this branch of speculation) founded on physical experiments which really seem to have some bearing on the subject, has lately been put forward by Professor Tyndall, who is disposed to regard the tails of comets as resulting from the formation of a species of actinic cloud by the action of the solar rays, *after* their character has been altered during their passage through the comet's head At present, however, it is difficult to say whether such a theory is well or ill founded, because we have so little positive evidence respecting the actual physical condition of cometic substance

COMETARY SPECTRA Mr Huggins has discovered that comets yield a spectrum consisting of three or four luminous bands much wider apart than those in the nebulæ Brorsen's comet, 1868, gives three bands not identical in position with those of any known substance, but the three bands of comet II of 1868 coincide with the spectrum of incandescent olefiant gas or carbon (see Mr Huggins's paper, *Phil Trans* 1868, p 529) (See *Spectrum*)

COMMUTATOR (*muto*, to turn) A piece of apparatus used, for making, breaking, and reversing a current from the battery, in connection with many electrical instruments

There are many forms of commutator, the arrangement used depending entirely on the purpose for which it is employed Frequently it consists of an ivory cylinder into which are let at intervals slips of brass whose number depends upon the connections to be made These slips are connected with each other in pairs, and the cylinder is turned upon its axis by means of a handle Against the surface of the cylinder springs press, which are connected with the batteries, galvanometers, or other instruments, by wires proceeding to binding screws attached to them When they press upon the ivory parts between the brass slips on the cylinder, connection is cut off, since ivory is an insulator, but when the ivory cylinder is turned round, and they press upon the brass slips, the circuit is completed, in any required direction, by means of the wires joining these slips.

Other commutators are described in connection with the instruments to which they are applied

COMPARISON OF THE INTENSITY OF TWO LUMINOUS SOURCES See *Photometry*

COMPASS Primarily an instrument for showing the magnetic north and south line, founded upon the power which the earth has of causing a magnet, supported so as to be capable of turning round a vertical axis, to take up a definite position Since, however, the phenomena of magnetism have become better understood, the name has been extended to include every instrument for examining qualitatively the directive tendency of the earth upon a magnet If, as is fully explained under *Magnetism, Terrestrial*, a magnetised bar could be freely suspended about its centre of gravity—that is, so as to be capable of turning in any direction whatsoever—it would take up a certain position depending upon its place on the earth's surface In England it would point nearly to the geographical north and south, and it would dip downwards at the same time, making an angle of about 70° with the horizontal plane An instrument for observing the north and south directive tendency or the *declination* is called a *declination compass*, or, more frequently, simply *a compass* An instrument for observing the *dip* or *inclination* is called an *inclination compass*, and frequently a *dipping needle* It is the first of these instruments which we shall now describe, as it is the one to which the word compass originally belonged the description of the other will be found below.

The history of this instrument is entirely unknown There is good reason for believing that the Chinese were acquainted with the use of it seven hundred years at least before it was employed by European nations The general use of it in Europe appears to have been introduced about the end of the thirteenth century It was known in the twelfth century, the first mention of it being made by a French writer of that period

The compass in its simplest form consists of a bar magnetised longitudinally, and supported by a vertical needle point, so as to be free to move in the horizontal plane A delicate method of suspension is obtained by boring through the bar, and attaching just above the hole a hollowed cup of agate or ruby, by which the bar rests upon a very fine needle point A sufficiently light magnet supported in this way is but little interfered with by friction The magnet thus suspended is placed inside a circular compass box and on a white card in the bottom of it the points of the compass (see *Rhumbs*), with half points and quarter points, are marked, and frequently the circumference of the card is divided into degrees and quarters of a degree By observing, then the direction in which the magnet points, and by knowing the *angle of variation* for the place of observation the true or geographical north and south line is determined The angle of variation is the angle by which the north and south line, as indicated by the compass, differs from the geographical north and south line (See *Magnetism, Terrestrial*) For Greenwich this angle is at present (1870) 19°55′ west—that is to say, the magnet points to the west of true north by that amount North of Greenwich the angle increases, thus at Edinburgh it is 2°5′ greater (See also *Compass Mariner's*)

COMPASS, THE AZIMUTH. The *azimuth* distance of any point in the heavens is the distance measured along the horizon between the foot of a secondary to the horizon through the point, and the point of intersection of the astronomical meridian with the horizon The same is the definition of the magnetic azimuth distance of a point, if for astronomical meridian, magnetic meridian be substituted The *Azimuth Compass* is an instrument for determining the magnetic azimuth of a point, and it is plain that, by knowing the astronomical azimuth, and likewise the magnetic azimuth of a point, we can at once determine the *variation of the compass* at the place of observation (See *Compass, Variation of*)

The Azimuth Compass is a mariner's compass, which has the card divided into degrees and quarters of a degree round the circumference, and at opposite points of the box are fitted two upright pieces of brass, with slits down the middle, through which the sun, star, or other object may be viewed These uprights are called the *sights* of the instrument A vertical wire or hair is stretched in the middle of one of the slits, the other is furnished with a triangular prism, arranged so as to reflect the division of the compass card just below the sight up to the eye.

This sight has also an eye-piece with coloured glasses to preserve the eyes when the sun is the object observed

In order to use the instrument, the whole box is turned round a vertical axis, till, on looking through the eye-piece and the sight opposite, the object to be observed appears through the slit, bisected by the hair, which passes down the middle of it At the same time, the prism reflects the divisions of the scale to the eye of the observer, and the number read off expresses the magnetic azimuth distance of the object

COMPASS, DECLINATION, or, *Declinometer* The instrument by which the angle of magnetic declination is determined—that is, the angle between the planes of the magnetic and geographical meridians (See *Declination, Declinometer,* and *Magnetism, Terrestrial*)

COMPASS, INCLINATION, or, *Dipping Needle* An instrument for measuring the angle of magnetic *inclination,* or the angle which a magnet, turning about a horizontal axis, and placed in the magnetic meridian, makes with the horizontal plane (See *Dipping Needle,* and *Magnetism, Terrestrial*)

COMPASS, MARINER'S A particular form of compass especially adapted to use at sea To the upper side of a magnetised needle turning upon a suitable pivot as described above (see *Compass*), is attached a circular plate of mica in the centre of which is traced a star with 32 rays, which are the *rhumbs* or *points of the compass* as they are called In order to avoid the effect of pitching and rolling of the ship, the compass is supported on *gimbalds* These are two concentric copper rings, the larger ring turns upon a horizontal axis whose extremities rest in the sides of the exterior case which contains the compass The interior ring turns upon an axis which passes through two opposite points of the circumference of the outside ring in a line at right angles to the axis on which it turns The compass is fastened to the inside ring, and its weight tends to keep the plane of the rings horizontal Thus supported, the compass-box and card always keep their position in spite of the pitching of the vessel A black vertical line is drawn inside the compass-box, so placed, that the line joining it with the point on which the card turns is that of the ship's motion, and thus the point of the card which stands opposite to it indicates the direction in which she is sailing, with reference to the magnetic meridian of the place For night sailing a lamp is arranged so as to throw its light up from beneath through the mica card, and the points, which are opaque, appear dark upon a bright ground

A great obstacle to the use of the compass is found in the magnetism of the ship itself An account of this will be found under *Magnetism of Ships* Various plans have been proposed for doing away with the effect of it, such as by placing near to the compass masses of soft iron, or by having a compass card distorted to suit the particular ship Since, however, the magnetism of the ship is not permanent, but alterable by change of position, by rough weather, and so on, these methods can never be wholy successful In large ships a compass is frequently placed at the mast head, and this being very much out of the influence of the local attraction the error of the deck compass can be determined by comparison This error is also frequently determined when possible by observing a distant object on shore and noting the effect on the Azimuth Compass while the ship is gradually swung, that is, has its head turned round to every point of the compass The *terrestrial variations* of the compass will be found discussed in a separate article (See *Compass, Variations of, Declination,* and *Magnetism, Terrestrial*)

COMPASS, POINTS OF THE See *Rhumbs*

COMPASS, SINE, more usually called a *Sine Galvanometer* Is an instrument for determining the strength of an electric current (See *Sine Galvanometer*)

COMPASS, TANGENT, more generally called a *Tangent Galvanometer* An instrument used for determining the strength of an electric current We have described it under *Galvanometer*

COMPASS, VARIATION OF. The term "variation of the compass," is frequently used as synonymous with *deviation of the compass,* or *declination of the compass* (See *Declination*)

COMPASS, VARIATIONS OF The magnetic elements, viz, the angles of declination and inclination and the intensity, do not always remain the same, but are subject to changes or *variations* both periodical and also irregular Of the former kind there are *secular variations,* or those which take very long periods of time, as centuries, for their completion, and there are also *annual* and *diurnal variations.* These variations as well as the irregular ones, it is the object of magnetic observatories to determine and to record The methods of doing so and the instruments used, will be found described under the proper heads (See *Observatory, Magnetic, Declinometer, Dipping Needle*) It is the nature of the variations we are concerned with here

The nature of the *secular variations* of magnetic declination will be best understood from examining the following table which gives the values of the angles at London for a number of years.

In 1576 the angle of declination was in England,			11° 15′ East
1622	”	”	6°
1660	”	”	0°
1730	”	”	13° West
1760	”	”	19°30′ W
1818	”	”	24°41′ W maximum
1850	”	”	22°29′
1870	”	”	19°55′

Thus it appears that in 1576, the first year of which we have any record, the needle pointed 11°15′ to the east of true north This angle gradually decreased till the year 1660, when the line of the needle was the same as the geographical north and south line The declination then gradually took a westerly value, increasing till the year 1818, when the needle pointed 24°41′ to the west of the geographical north This was its maximum, and from that time till the present the angle has been diminishing At present, 1870, the magnetic needle points 19°55′ west of true north On examining the table it is easily seen that the rate of change per annum is not always the same In approaching the geographical meridian, it appears to be accelerated, and in approaching its maximum value to be retarded The present rate of decrease is about 8′ per annum Similar variations of the needle are observed at other places on the earth's surface, but the amounts and the directions of these variations are not the same for different places Thus at Paris the time of maximum westerly declination was the year 1814, and in that year the amount of it was 22°34′.

In 1780 Cassini discovered that the angle of declination is subject to a certain annual variation According to him the westerly declination is greatest at the vernal equinox From that time till the summer solstice it is gradually diminishing, and from the summer solstice to the vernal equinox it again slowly increases The amount of this annual variation is small It differs at different periods, its average range at Kew is about 59″

Lastly, the declination is, as has been mentioned, subject to diurnal variations, discovered by Graham in 1722 At about 8 in the morning the north end of the needle is pointing about 4′ to the east of its mean position From that time till 1 P M it turns more and more towards the west, and at that hour stands about 6′ to the west of the mean It then turns backwards to the east, and after a very slight westerly excursion, between 12 midnight and 3 A M, it regains its first position at 8 A M, when it recommences the same series of changes We have described here an average course for Kew The amount varies at different parts of the year, and very much at different places The nature of the change is, however, similar for places having northern magnetic latitude, and the same description holds for the southern magnetic hemisphere, if the names of the poles be interchanged, and the directions of the variations altered

The magnetic inclination is also subject to periodic changes Since the year 1720 it has been gradually decreasing In that year it was 74°42′, in 1800, 70°35′, in 1850, 68°48′; and in the present year, 1870, 67°55′ It is evident from these numbers, which are all in the decreasing direction, that as yet we know nothing of a complete cycle of change There are also small annual and diurnal variations According to Hanstein it is about 15′ greater in summer than in winter, and the same observer states that it is about 4′ greater in the morning than in the afternoon

So far but little is known of the variations of magnetic intensity In 1865 the total intensity was, in British magnetic units, 10 28, in 1870, 10 24. The horizontal force (1870) is 3 83, and the vertical 9 49 (See *Intensity, Magnetic*)

We have mentioned above that, besides the periodical variations, there are others which are not periodical, and which have hitherto been to us occurrences without regular law To these have been given the name *magnetic storms*, and an account of them will be found under that head

COMPENSATION PENDULUM In order that the oscillations of a pendulum may be isochronous, the distance between the centre of suspension and the centre of oscillation must be invariable (See *Pendulum*) If the pendulum consist of a simple wire, this length will vary with the temperature, and therefore the time of oscillation will vary, hence the length of the simple equivalent pendulum should be independent of temperature Compensation pendulums are so constructed that the lowering of the centre of oscillation, by the extension of one part of the pendulum, is compensated for by the extension of other parts in the opposite direction There are three common forms of compensation pendulum The first is the *gridiron pendulum* It consists of a steel rod, oscillating about a point of suspension, and bearing a rectangle of steel, the lower bar of this rectangle supports two rods of brass passing vertically upwards, which with a horizontal bar of brass form a second rectangle within the first To the horizontal brass rod is attached a third rectangle of steel, and within this again, and

attached to the base, is a fourth rectangle of brass, the horizontal bar of which bears the central rod and bob of the pendulum Now the steel rods elongate downwards with a rise of temperature, and the brass rods upwards, consequently they may be so arranged that in spite of variation of temperature the centre of oscillation shall remain at the same distance below the centre of suspension In order that this result may be attained the sum of the lengths of the vertical steel rods must be to the sum of the lengths of the vertical brass rods in the inverse ratio of the coefficients of expansion of steel and brass Now the coefficients of expansion of steel and brass are to one another as 5 to 9 nearly, therefore the sum of the lengths of the steel bars must be to the sum of the lengths of the brass as 9 to 5

The second kind is Martin's *compensation pendulum* It consists of an ordinary pendulum, with a metallic bar placed horizontally across the pendulum rod, and bearing at its extemities two heavy balls The horizontal bar is composed of two bars of different metals soldered together, the upper one expanding less than the lower for a given rise of temperature Hence when the bar is warmed it bends into a curve, so that although the pendulum bob is lowered in consequence of the expansion of the central rod, the balls at the end of the horizontal bar are raised, hence if the material length and weight of the bar and balls be properly chosen, the centre of gravity of the whole pendulum, and, therefore, the centre of oscillation remains unchanged

A third kind of compensation pendulum is Graham's *mercurial pendulum* The rod of the pendulum is steel, and the bob a hollow glass cylinder containing mercury When the temperature rises the steel rod elongates, but the mercury rises, and since the expansion of the mercury is greater than that of the steel, the one may compensate for the other, so that the position of the centre of oscillation remains the same

COMPLEMENTARY COLOURS (*Complementum*, *com*, together, and *pleo*, to fill) Complementary colours are those which are in the greatest degree opposed to one another, and which therefore, when mixed together, produce white light or neutrality The following are the principal colours and their complementaries —

Red . Green Orange Blue Yellow . Violet

COMPOSITION OF COLOURS See *Colours, Composition of*

COMPOSITION OF FORCES The transformation of one system of forces to another system which will produce the same mechanical effect The principles of the composition of forces depend on geometrical theorems, by means of the fact that the three elements which define a force, may be represented by a straight line, for example, the extremity of the line may represent the position of the point of application of the force, the direction of the line the direction of the force, and by selecting a unit of length to represent a unit of force, the length of the line will represent the magnitude or intensity of the force The single force, which will have the same effect as several others is termed their *Resultant* To apply the theorems of geometry to the composition of forces, the following principles are required

1 *The Principle of the Transmissibility of Force.* A force may be applied at any point in the line of its direction, provided this point be connected with the first point of application by a rigid and inextensible straight line

2 The resultant of a number of forces acting on the same straight line also acts along this line, and its magnitude is found by taking the sum of the components, acting in one direction, from the sum of those which act in the other direction, the direction of the resultant being that of the greater sum

3 When two equal forces act on the same point, the resultant bisects the angle between them

4 From these is deduced the parallelogram of forces When two forces, acting on a point, are represented by two adjacent sides of a parallelogram, their resultant is represented by the diagonal of the parallelogram passing through the point of application

5 The resultant of two parallel forces is parallel to each of the components, and is equal to the sum of the two components when they are alike in direction, and to their difference when they are unlike In the former case the resultant lies between the components, and in the latter beyond the greater, and in the same direction as the greater The position of the resultant is given by the fact that when each of the components is multiplied by its distance from the resultant, the two products are equal, in other words, the distances of the forces from the resultant are inversely proportional to the forces When, however, the parallel forces are equal in intensity and opposite in direction, they have no single resultant, and can only be counteracted by a similar pair of equal forces Two equal and opposite forces are termed a couple (See *Couples*) When a number of forces act at different points in a body, they can always be reduced either to a single resultant, or to a single resultant and a couple In order that a body may be in equilibrium under the action of a system of pressures, both resultant

and resultant couple must be zero, that is to say, the forces must neither give to the body a motion of translation, nor a motion of rotation

COMPOUND MACHINES Any combination of simple machines is termed a compound machine The mechanical advantage of a compound machine is the product of the mechanical advantages of the separate simple machines By the combination of several levers so that the weight of one is applied as the power of the next, and so on, we avoid the necessity of largely increasing the length of the power-arm, in order to obtain sufficient advantage by the use of one lever only, and we distribute the pressure on the fulcrum over several points For application of these principles see *Weighing-Machines*, *Crane*, *Crab*, *Capstan* Of course the increase of power gained by the use of compound machines is attended by a corresponding diminution in the velocity with which the weight is moved

COMPOUND MICROSCOPE A compound microscope consists essentially of an object-glass and an eye-piece, connected by a tube eight or ten inches long, firmly supported on a heavy foot, and fitted with rackwork or sliding adjustment to enable the tube to be raised or lowered along its axis Below the eye piece, and firmly attached to the stand, is a stage for supporting the object under examination In the best instruments this stage is fitted with rotating arrangements and screw adjustments in all directions, so as to enable any portion of the object to be examined without removing the eye from the eye piece Underneath the stage is fitted illuminating apparatus, by which a beam of lamp or day light reflected from a mirror may be converged on to the object (See *Illuminating Lens*; *Concave Mirror*) The object glass consists of a combination of *plano convex achromatic lenses*, so arranged as to be free from *spherical aberration* The equivalent focus of these may vary from three and four inches down to the fiftieth of an inch, the $\frac{1}{2}$ and $\frac{1}{4}$ inch being the most generally useful The object-glass is brought down to the object until they are at such a distance apart that an enlarged image of the object is formed in air at about 8 or 10 inches above it This enlarged image is then received upon the eye piece, where it is again magnified (See *Microscope*, *Object-glass*, *Eye-piece*, *Positive Eye piece*, *Negative Eye piece*)

COMPOUND PRISM In order to obtain a prism of a larger size than can be conveniently made from one piece of glass, several prisms may be cemented together, one over the other, base to apex, on the principle of the *polygonal lens* or *Fresnel's lens*, which see

COMPRESSIBILITY The quality of bodies in virtue of which they can be made to occupy a smaller space All bodies are more or less porous, so that the molecules of which they are composed are not absolutely in contact (See *Porosity*) Hence all bodies are compressible, gases are the most compressible, and obey the law of Boyle that the volume varies inversely as the pressure When, however, great pressure and cold are applied, most of the gases become liquids Oxygen, hydrogen, and nitrogen have not yet been liquified

COMPRESSIBILITY OF LIQUIDS For a long time it was supposed that liquids were absolutely incompressible The experiment known as the *Florentine Experiment* was held to point to this conclusion A hollow metallic globe said to be of gold, and also of lead, was filled with water and perfectly soldered This was submitted to great pressure Since of all solids, for the same surface a sphere has the greatest contents, it follows that if none of the water escape, any flattening of the globe must be attended either by a diminution of the volume of contained water, showing its compression, or by a stretching of the metal It was found that the water was forced through the metal, appearing as dew on the outside (Compare *Hydraulic Press*) This was viewed as a proof that the water was incompressible That water, mercury, and several other liquids are compressible, and their compression measurable, was shown by Œrsted A greater number of liquids were examined by Colladon and Sturm, with somewhat different results The instrument employed, called a *Piezometer*, consists of a glass globe, on to the neck of which is fused a long capillary tube The capacity of the globe is ascertained, as also that of the capillary tube, so that the ratio between the entire capacity of globe and tube and any portion of the tube may be known The capillary tube bears a scale The globe and tube are completely filled with the liquid under examination, and inverted into a little trough of mercury On gently warming it a little of the liquid is expelled, so that when the original temperature is restored, the mercury rises in the tube to a convenient height Side by side with this globe is placed in the mercury a cylindrical tube closed at the top, open at the bottom, and graduated into divisions showing equal units of volume This latter tube serves as a manometer (see *Manometer*), since the diminution of the air in it when under pressure is a measure of the pressure (See *Elasticity of Gases*) The two neighbouring vessels are, together with the mercury trough, enclosed in a very strong glass cylinder, permanently closed at the bottom, and capable of being closed at the top by a screw head into which is fastened the delivery tube of a force-pump The glass cylinder is completely filled with water, its head screwed on, and the delivery tube of the force-pump, which is fed with water, is inserted On working

the pump the pressure is transmitted through the water to the mercury, and forces the latter up the capillary tube, and also up the manometer tube The first of these effects must be due to the compression of the liquid in the glass globe The second is, of course, due to the compression of the air Since (see *Elasticity of Gases*) the volume of a gas varies inversely as the pressure to which it is subjected, it is easy, by reading the height of the mercury in the manometer tube, to find the pressure to which the interior of the apparatus is subjected By reading the height of the mercury in the capillary tube and knowing the capacity of this tube in comparison with that of the globe, the amount of compression on a given volume is determined, which corresponds to and is effected by the given pressure Although in this piezometer the pressure on the outside is the same as that on the inside, yet Regnault has shown that this circumstance is not sufficient to ensure that the piezometer shall remain of constant capacity In Regnault's form of the apparatus, the piezometer bulb and the interior of the compression cylinder could each, by means of four cocks, be separately or together put in communication, either with the external air or with a vessel of compressed air By this means, on the one hand, the compression of the piezometer tube when subjected to pressure could be measured On the other, the total apparent shrinking of the liquid, due partly to its actual compression and partly to the expansion of the piezometer tube, when the pressure was exclusively applied to the latter, could be measured Hence the true compressibility of the liquid could be deduced A few of the results obtained by Grassi, who employed Regnault's method, are appended The pressure employed is one atmosphere

Mercury	at	32°F	shrank	3	millionths of its volume		
Water	,,	32	,,	50	,,	,,	
Water	,,	107	,,	44	,,	,,	
Ether	,,	32	,,	111	,,	,,	
Ether	,,	57	,,	140	,,	,,	
Alcohol	,,	45	,,	84	,,	,,	
Chloroform	,,	54	,,	65	,,	,,	

COMPRESSION (*Con*, together, and *premo*, to press) In astronomy the compression of a planet is the amount by which the polar axis falls short of the equatorial It is commonly expressed by the ratio which the difference of the two diameters bears to the greater Thus if the compression of a planet be spoken of as one-tenth, what is meant is that the excess of the equatorial diameter over the polar is one-tenth of the former diameter

COMPRESSION AND DILATATION OF SOLIDS, INFLUENCE OF, ON LIGHT When a piece of well annealed glass is examined in the polariscope, no effect of double refraction is seen, but by slightly bending it between the fingers, or compressing or dilating it in any other way, coloured fringes are produced, showing that compression or dilatation communicates a doubly refracting structure to it Similar effects are produced with jelly. (See *Circular Polarisation*, *Chromatic Dynamometer*)

COMPRESSION, ELECTRICITY OF It was observed by Hauy that when a piece of calcareous spar is pressed between the fingers it becomes positively electrified, and will keep its electrification for days together Many other minerals, such as fluor spar, topaz, mica, have a similar property, becoming either positively or negatively electrified when pressed The electricity developed in this way is frequently spoken as *electricity of compression* This excitation by pressure does not appear to be a property belonging only to crystalline or mineral bodies Many other substances, when pressed together in pairs and then separated, exhibit electric excitement, one becoming positive and the other negative. Thus if a disc of cork and one of caoutchouc, held on insulating handles, be pressed together and then separated, the cork is found positively, and the other negatively, electrified It is difficult, however, to separate the effects due to compression from those due to friction In the case of compression as in that of friction much depends upon the nature of the surfaces, whether rough or smooth, polished or unpolished, and the unequal distribution of heat between the two substances brought into contact likewise affects the result

CONCAVE LENS, DOUBLE (*Concavus*, hollow) A lens bounded by two concave spherical surfaces, which causes parallel rays of light to diverge If the radii of its curvatures are alike, it is said to be equally concave, but, if otherwise, unequally concave

CONCAVE MIRROR A reflecting surface of a concave form It converges incident parallel rays to a point in front of it called the *principal focus* The distance of the focus from the mirror is one-half the radius of concavity Divergent rays, falling on a concave mirror from a somewhat distant point, will be converged to a focus beyond the principal focus The radiant point and this new focus are called *conjugate foci*, because if one is the radiant point, the other will be the focal point Converging rays, falling on a concave mirror, come to a point within the principal focus. A concave mirror will form at its focus a small and highly

luminous image of any object in front of it, and when of large size and considerable concavity it will concentrate the sun's rays, and become a very powerful *burning mirror*. A concave mirror, worked to a parabolic curve, is free from spherical aberration. (See *Parabolic Mirror*.)

CONCAVO-CONVEX LENS. A lens having one concave and one convex surface, but differing from a meniscus lens in that the concavity exceeds the convexity. It acts as a concave lens, and causes parallel rays of light to diverge.

CONCAVO-CONVEX PRISM. See *Prismatic Lens*.

CONDENSER. A condenser is an instrument for collecting electricity. Its principle is founded upon induction, and it consists essentially of two conductors insulated from each other, and placed in such a position that induction may favourably take place between them. There are various forms, but all of them are modifications of what is known, from the name of its inventor, as Æpinus' Condenser.

Æpinus' Condenser consists of two circular brass plates placed opposite to each other, and supported, with their planes vertical, on glass pillars. The feet of the pillars are fixed to pieces of wood sliding in a frame common to them, and the distance between the plates can thus be altered at pleasure. Generally a third vertical pillar supports a plate of glass, or other insulating matter, between the two brass plates. Let us call one of the brass plates A, and the other B, and suppose A be connected with the prime conductor of an electric machine, B with the earth. Now let a charge of positive electricity be communicated to A. Inductive action takes place between the plates, and negative electricity is induced and made *latent*, *bound*, or *dissimulated*, as it is called, upon B. This in its turn makes latent a certain proportion of the electricity upon A. It is evident, therefore, that on account of this inductive action a much larger quantity of electricity can be put upon the plate A when B is present than when it is not. The extent to which the "dissimulation" by means of induction takes place depends upon the nearness of the plates, and upon the *specific inductive capacity* of the material between them. (See *Induction*, *Capacity*, *Specific Inductive*.) If now B be removed from the vicinity of A, the electricity on A which was formerly held bound on the side nearest to B spreads over the plate, and can make its action manifest towards external objects. The condenser can therefore be made use of for the purpose of discovering electricity in sources, which, though weak, are capable of continuous action.

Volta's Condensing Electroscope consists of an ordinary gold leaf electroscope, to the top of which is attached a horizontal plate of brass (A) of considerable size. This is usually covered with shell-lac which forms the insulating dielectric. On the top of this the plate B is placed, and to it is attached an insulating handle. If a weak source of electricity, such as a dry pile, be put in connection with A, while the plate B is touched with the finger, the inductive action which we have just described takes place. If the finger is now removed, and then the dry pile, and if the plate B is carried away by its insulating handle, the bound electricity on A makes itself manifest by the repulsion of the gold leaves. The plate B is of course found to be electrified with the kind of electricity opposite to that of A.

CONDUCTION, ELECTRIC, is the transference of electric force through the medium of a conducting body. (See *Conductor*, *Electricity*, *Electrostatics*.)

CONDUCTION OF HEAT. (*Con*, together; *duco*, to lead.) When a bar of metal is heated at one end, it receives the motion which constitutes heat by direct contact, and transmits it from molecule to molecule along its length, until, at a certain distance from the source, the heat lost by radiation and convection is equal to that received, when the temperature of the rest of the bar ceases to rise. This propagation of heat through bodies is called *conduction*, and it varies with the nature of the substance.

1. *Conduction of Heat by Solids*. If a bar of copper and another of glass, of the same length and thickness, are placed in the fire, we find that the copper becomes hot much sooner than the glass; in fact, we may easily hold a rod of glass in the hand at a few inches from a red hot portion of it. Again, if a silver spoon, and another of German silver or pewter are placed in the same vessel of hot water, the silver spoon becomes excessively hot, while the pewter spoon is no more than warm. This is due to the fact that silver conducts heat far better than pewter; and all substances thus considered have been divided into good and bad conductors of heat; the term *non-conductor* of heat cannot be said to exist, because all substances, as far as we know, conduct heat to a certain extent. The variation in the conducting power of different substances was shown by Ingenhouz, by placing a number of bars of different substances, with one end in contact with hot water or hot oil, and noting the extent to which wax was melted from their surfaces; or a compound bar, one half of which is of iron, and the other of copper, may be heated at the juncture, while small pieces of phosphorus are placed on each of the remote ends; it will now be found that the phosphorus will take fire at the end of the copper bar, sooner than on the iron bar at the same distance from the source of heat. The following table

shows the relative conductivity of some of the metals for heat according to the determinations of Wiedemann and Franz, the conductive power (or as it is sometimes called *thermal conductivity*) of silver being taken as 100

Name of Substance	Conductivity	Name of Substance	Conductivity
Silver	100·0	Iron	11·9
Copper	73·6	Lead	8·5
Gold	53·2	Platinum	8·4
Brass	23·6	German Silver	6·0
Tin	14·5	Bismuth	1·8

The conduction of heat varies with the temperature, and Forbes has found that the conductivity decreases as the temperature of the substance increases, thus if the conductivity of a bar of iron at 0° C be represented by 0·1337, at 100° C, it is 0·1012, at 200° C it is 0·0876, and at 275° C it is 0·0801 The conduction of heat is influenced by the specific heat of a substance, and Tyndall has given the following experiment in exemplification of this If we take two small cylinders, one of iron and the other of bismuth, of precisely the same dimensions, and place them on a hot surface, we notice that wax placed upon the upper extremity of the bismuth cylinder, melts sooner than wax placed upon the iron cylinder Yet, by the above table, it is seen that iron conducts heat far better than bismuth, hence we should expect the wax on the iron cylinder to be melted before that on the bismuth cylinder But while the conducting power of iron is 11·9, and that of bismuth 1·8, the specific heat of the former is 0·1138, and that of the latter 0·0308 (See *Specific Heat*) Thus iron requires nearly four times as much heat to raise its temperature through a certain number of degrees, as bismuth Therefore, although the iron is receiving, in a given time, more heat than the bismuth, a less amount of this becomes sensible heat, that is, the temperature is less quickly raised, consequently the temperature at which wax melts is sooner attained by the bismuth than by the iron

When we touch a good conductor of heat it feels cold, because it rapidly receives heat from the hand If we successively touch silver, lead, marble, wood, and wool, at the same temperature, the silver will appear colder than the lead, the lead than the marble, the marble than the wood, and the wood than the wool, because the conductivity of these bodies varies, and they consequently receive heat from the hand with varying degrees of readiness Our clothing is composed of substances which conduct heat badly, and therefore prevents the rapid radiation of heat from the body. It may appear anomalous that we wrap ice in a blanket to keep it from melting while we use the same article for promoting warmth, but it must be borne in mind, that, in the one instance, the badly conducting wool prevents the passage of heat *from* our bodies, while, in the other, it prevents the passage of heat *to* the ice The fur of animals, the plumage of birds, and the bark of trees, are all bad conductors of heat According to Count Rumford the fur of the hare is the worst conductor of heat with which we are acquainted, and eider down is nearly as bad, while wool and silk follow close behind Tyndall found that the bark, as compared with the wood of the pine tree, conducts heat to an extent corresponding to a deflection of 7° of the galvanometer, compared with 12°, a very delicate thermopile being employed in the experiments The temperature of the blood, both of man and animals, is far above the mean temperature of the air, and if the heat generated by the oxidation of carbon within the organism, were rapidly dissipated, death would ensue, because vital functions could not be carried on at such a diminished temperature, hence, in arctic regions, men unprovided with the necessary clothing die, as also does a bird stripped of its plumage, or a tree of its bark

The molecular condition of a substance has a great influence on its conducting power Compact and dense substances conduct heat, as a rule, better than light and porous substances This is well exemplified in the difference in conducting power between compact wood and porous bark The same substance conducts differently, if it be in the solid or pulverulent form, thus wood conducts better than sawdust, rock crystal better than sand Air must be assumed to be a bad conductor and in porous substances we have an innumerable number of air spaces If a thin layer of asbestos is placed on the palm of the hand, a red-hot ball of metal may be held with impunity, for the asbestos, in virtue of its structure, is an extremely bad conductor of heat As another example of the influence of molecular structure upon conductivity, may be mentioned the fact, observed by Svanberg and Matteucci, that bismuth conducts heat better in the direction of the planes of cleavage, than at right angles to them De la Rive and De Candolle found that wood conducts better parallel to its fibre than across it In the case of oak, Tyndall found, that under precisely similar conditions, the conduction of heat (expressed in deflec

tions of the needle of the galvanometer), was 34° parallel to the fibre, and 9.5° perpendicular to the fibre, and parallel to the ligneous layers. As regards crystals, M. de Senarmont has found that the conduction of heat takes place with greater readiness in some directions than in others. If the crystal belongs to the regular system, the conductivity is equal in all directions; if it belongs to the second or third systems, the conductivity is greater in the direction of the crystallographic axis than across it; while in other crystals the conductivity varies in three directions.

2. *Conduction of Heat by Liquids.* The conductivity of liquids is very slight. Water may be boiled over a piece of ice, and, when heated from above, it is found to acquire heat very gradually. A few experiments on the subject were made by Rumford, Thomson, and Murray, and more recently by M. Despretz (*Annales de Chimie et de Physique*, 1839, p. 206.) The latter physicist employed a cylindrical vessel of wood, 39 inches high, into the side of which he placed a number of thermometers arranged horizontally, so that their bulbs were inside, and the greater part of their stems outside the cylinder. The latter was filled with water, which was heated from above by means of a copper vessel in contact with the water surface, into which hot water was allowed to flow at intervals. After the lapse of a number of hours the thermometers became stationary at different heights, from a comparison of which M. Despretz concluded that the conduction of heat by water follows the same law as conduction by solids; and he calculated that water possesses about one hundredth part the conductivity of copper. Quite recently Professor Guthrie has investigated the subject of liquid conductivity, and the following are some of the results obtained. (*On the Thermal Resistance of Liquids*, "Philosophical Transactions," 1869.) He considers that liquids possess a great advantage over solids in all exact experiments on the conduction of heat, on account of their greater homogeneity, "because no two specimens of the same solid substance are physically identical," while "under like external circumstances, two equal volumes of the same liquid are identical." The principal object of the investigation was to determine "the conductive indices or thermal resistances of the elements, and to determine the effect on such resistance caused by the change of chemical nature and of molecular construction of bodies." By *thermal resistance*, is meant the resistance offered by substances to the passage of heat through them by conduction, and for the determinations, an instrument called a *diathermometer* (which see), was employed. The following are some of the conclusions arrived at:—"The solution of a metallic salt in water invariably increases the thermal resistance of the water. Those elements which dissolve in the water without increasing the bulk of the water, can only increase its thermal resistance by increasing its capacity for heat, which must, in such cases, be the sum of the capacities of the water and elements separately. The thermal resistance of a solid salt is greater than that of water; consequently, whereas, in the majority of instances, water is displaced by the salt, the increased resistance is due to the partial substitution of a body of greater resistance." In the succeeding table, numerical results are given; the *specific thermal resistance* of each substance being obtained by dividing its resistance by that of water, which possesses the least resistance of any substance on the list, perhaps the least of all transparent liquids. The *thermal resistance in millimetres*, shows the corrected number of millimetres to which the column of liquid in the diathermometer (a kind of air thermometer), was depressed.

Name of Substance.	Thermal Resistance in Millimetres	Specific Thermal Resistance
Water	4.13	1.00
Glycerine	15.85	3.84
Acetic Acid (glacial)	34.63	8.38
Acetone	35.14	8.51
Oxalate of Ethyl	36.56	8.85
Sperm Oil	36.56	8.85
Alcohol	37.53	9.09
Acetate of Ethyl	37.53	9.09
Nitrobenzol	40.81	9.80
Oxalate of Amyl	41.29	10.00
Butylic Alcohol	41.29	10.00
Acetate of Amyl	41.29	10.00
Amylamine	41.88	10.14
Amylic Alcohol	42.26	10.23
Oil of Turpentine	48.53	11.75
Nitrate of Butyl	49.01	11.87
Chloroform	49.98	12.10

Name of Substance	Thermal Resistance in Millimetres	Specific Thermal Resistance
Bichloride of Carbon	53 35	12 92
Mercury Amyl	53 35	12 92
Bromide of Ethylen	54 34	13 16
Iodide of Amyl	54 80	13 27
Iodide of Ethyl	58 66 (?)	14 20 (?)

An experiment with mercury gave 0 13 as the specific thermal resistance, but Professor Guthrie gives this number with great reserve, on account of various experimental difficulties At all events the resistance offered by mercury to the conduction of heat is far less than that of water

3 *Conduction of Heat by Gases* Experiments on this subject are much needed, and are beset with numerous difficulties, the principal being the fact that gases, as also liquids, are much influenced, when heated, by an action termed *Convection* (which see) Rumford did not allow that gases possess any conductive power for heat, while the late Professor Magnus considered the conducting power of hydrogen comparable to that of a metal This assertion, which has been much disputed, was founded on various experiments, the principal being the following which illustrates the great readiness with which hydrogen cools heated substances Professor Magnus took a narrow tube, placed a platinum wire in its axis, and filled the tube with hydrogen Now, although the wire was readily maintained at a red heat (by means of an electric current), when the tube was vacuous, or full of air, he found that the hydrogen prevented incandescence The heat appeared to be so rapidly removed from the wire that it could not rise to redness, as if the hydrogen gas *conducted* heat from the wire He also heated a vessel of hydrogen, containing cotton wool (to prevent the formation of gaseous currents) from above, and found that the heat passed more rapidly downwards through hydrogen than through air Professor Tyndall traces the results to convection, and considers the conductibility of gases an open question (See also *Convection*)

CONDUCTION OF SOUND See *Propagation of Sound*

CONDUCTOR, ELECTRIC If a charged gold leaf electroscope be touched with a wire or metal rod in connection with the earth, it is at once seen to be discharged, but if it be touched with a rod of glass or a stick of shell lac discharge does not take place The electricity is able to pass away to the earth through the metal, whereas the glass or shell-lac has not the power to effect this transference The phenomenon which we have here mentioned is called *conduction*, the metal is called a *conductor* of electricity, and the glass and shell lac are called *non-conductors* or *insulators* (See also *Electricity*, *Electrostatics*)

Among bodies the widest difference exists with regard to their conducting power Some bodies at first sight (though on closer examination this turns out not to be really the case) appear to offer no obstacle to the passage of electricity through them, some conduct it with difficulty, while through some it seems unable to pass at all Speaking in the first place of electricity of high tension, such as that which is produced by the electric machine, the following list may be given

Conductors	Semi-Conductors	Non-Conductors.
Metals	Alcohol and Ether	Dry oxides
Gas Carbon	Powdered glass	Ice at $-25°$ C.
Graphite	Flowers of sulphur.	Fatty oils
Acids	Dry wood	Caoutchouc
Aqueous solutions.	Ice at $0°$ C.	Air and gases.
Water		Dry vapours.
Vegetable substances.		Silk
Animal substances.		Diamond.
Soluble salts		Glass
Linen		Wax
Cotton.		Sulphur.
		Resin
		Amber.
		Shell lac.
		Paraffin

In the first column are placed the substances which conduct best, in the last the best insulators, while the bodies in the second column hold an intermediate position with regard to power of conduction As we have said, however, no body is really a perfect conductor, none really permits the electricity to pass without resistance, nor is there any perfect insulator, and there is no line where conductive power can be said to cease, and insulating power to begin.

When we come to consider the conduction of a current of electricity produced by a galvanic cell or battery, which is presented in quantity, enormous as compared with that obtainable from the most powerful electric machine, but which at the same time possesses but little tension or power to overcome resistance, we notice still more minute differences in conductivity. We find that the metals which we have grouped together in the list above, differ widely from each other. The numbers in the following table show this; in it the conducting powers are compared with that of silver which is the best conductor, and which is taken as 100.

The conductivity of Silver being 100		The conductivity of Silver being 100	
That of Copper is	77.4	That of Platinum is	10.5
Gold	55.2	Lead	7.7
Sodium	37.4	German Silver	7.7
Aluminium	33.8	Antimony	4.3
Zinc	27.4	Mercury	1.6
Potassium	20.8	Bismuth	1.2
Iron	14.4	Graphite	0.069
Tin	11.4		

The numbers given above are the results of experiments by Mathiessen. They are taken at a temperature 32° F. (0° C.). The accurate determination of them is a matter of great difficulty, owing to the alteration produced by the presence even of a minute impurity in the metal. The molecular condition of the specimen has also a very marked influence. Thus, the difference in conductivity between hard drawn silver wire and the same annealed may amount to over 8 per cent. of the whole; the resistance being increased, and therefore the conducting power diminished by hardening the wire. For full information on this subject, see the Reports of the Committee appointed by the British Association for the Advancement of Science to consider the standards of electrical resistance, which are published along with the other reports of the Association from 1862 downwards.

The conductivity of metals is very much diminished by an increase of temperature, and hence it is always necessary to state the temperature at which it has been determined. Between 32° F. (0° C.) and 212° F. (100° C.) the difference sometimes amounts to 35 per cent. of the whole conducting power, and in a large number of metals and alloys is as much as from 20 to 30 per cent. The results of Matthiessen on this subject also are given in the reports above referred to.

Faraday considers that the difference between conductors and non-conductors is one only of degree. Induction, he says, is a necessary preliminary to conduction. "Conduction and insulation appear to consist in an action of contiguous particles dependent on the forces developed in electrical excitement; these forces bring the particles into a state of tension or polarity which constitutes both induction and insulation; and being in this state the contiguous particles have a power or capability of communicating their forces one to the other, by which they are lowered and discharge occurs." This discharging of contiguous particles one into another he holds to be conduction.

CONDUCTOR, NEGATIVE. That part of an electric machine which is arranged to collect negative electricity. (See *Conductor, Prime*, and *Electric Machine*.)

CONDUCTOR, PRIME or POSITIVE. That part of an electric machine which collects the positive electricity is called the *Prime* conductor; the part which collects negative electricity is called the *Negative* conductor. In the ordinary plate electric machine, the prime conductor is an insulated body of conducting material carrying a row of points close to which moves the glass plate as it turns, and so charges the conductor. The negative conductor is insulated and connected with the rubbers, which, becoming negatively electrified, electrify it similarly. As is explained, however, in our article upon *Electric Machines*, both of the conductors cannot be insulated at the same time. (See also *Electric Machine*.)

CONGELATION. (*Gelu*, frost; *congelo*, to freeze.) The passage of liquids to the solid condition is termed congelation. It is applied more particularly (as the name imports) to substances which, ordinarily existing in the liquid condition, are caused to congeal by the application of cold. Thus we should speak of the *congelation* of water, but of the *solidification* of molten iron; indeed, the latter term has almost entirely supplanted the former, whether it be applied to liquids such as mercury, which become solid at a very low temperature, or to molten platinum which becomes solid at a very high temperature. (See *Solidification*.)

CONICAL REFRACTION. (*Conus*, κωνος, a point; Sanscrit, *co*, to bring to a point.) While considering the nature of biaxial crystals, Sir William R. Hamilton arrived at the unexpected conclusion that under certain circumstances there would not be two emergent rays, but a *cone of rays diffused from a point*, manifesting themselves in the form of a luminous circle

This was a pure prediction from mathematical reasoning, for no phenomenon in the remotest degree akin to it had ever been noticed or anticipated The experimental verification was accomplished by Prof Lloyd at Sir William's request, who found that the prediction was in every way confirmed by facts For further particulars see Nichol's Cyclopædia of the Physical Sciences, article *Refraction*

CONIINE —An intensely poisonous volatile alkaloid extracted from the hemlock (*Conium Maculatum*) Formula $C_8H_{15}N$. When pure it is a colourous limpid liquid boiling at 163 5°C (326°F) Specific gravity 0 87 The odour is peculiar and repulsive, somewhat resembling tobacco , it is a strong base, and neutralises acids to form salts.

CONJUGATE FOCI (*Conjugo, con,* together, and *jugum,* a yoke) See *Concave Mirror*

CONJUNCTION (*Con,* together, and *jungo,* to join) In astronomy two planets are said to be in conjunction when they have the same longitude , when a planet is simply said to be *in conjunction,* it is to be understood that the planet is in conjunction with the sun The symbol expressing conjunction is ☌ A planet whose orbit lies nearer the sun than the earth's orbit can be in conjunction in two ways, viz —either between the earth and the sun, or beyond the sun In the former case the planet is said to be *in inferior conjunction,* in the latter *in superior conjunction* As an aid to the memory in distinguishing the two it may be pointed out that only an inferior planet can ever be in inferior conjunction

CONJUNCTIVA A delicate mucous membrane which covers the interior of the eyelids and front portion of the eye (See *Eye*)

CONNECTING RODS In the steam engine the iron bars which connect the piston rod with the wheels They are either attached directly to the spokes of the wheels, or to cranks constructed on the axles between the wheels There is a joint at each end of a connecting rod, arranged so that while one end makes one complete stroke in a straight line backwards and forwards with the piston to which it is attached, the joint connected with the spoke or crank makes a revolution round the axis of the crank, and so causes the crank or wheel itself to revolve (See *Engine*)

CONSECUTIVE POINTS OR POLES A name applied to certain parts of an artificial magnet at which a peculiar distribution of magnetic force is found An evenly magnetised bar may be looked upon as being made up of a series of elementary magnetic bars, all having their like poles pointing in the same direction , and, in fact, this will be found to be the case if the bar be broken up, and each of the fragments examined The aggregate effect of all these elementary magnets is to give a bar, having at one end a strong north pole, and at the other a strong south pole, the intensity of the magnetic force gradually decreasing from each end towards the middle But if the bar be not evenly magnetised at some place between the two ends, there may be found a series of these elementary magnets with their poles turned the opposite way to that of the elementary portions of the mass of the bar The consequence of this is that, at the extremities of this series, there are found distinct poles, instead of the even distribution from end to end, and if the bar be broken at these points, it will be found that at one place two north poles come together, and at the other two south poles These places of disturbed distribution are called *consecutive poles or points*

CONSEQUENT POINTS Same as *Consecutive points or poles,* (*q v*)

CONSERVATION OF ENERGY This principle applies either to a machine or body left to itself, or to the universe as a whole, and asserts that the sum of the different kinds of energy in the body, and the total amount of energy in the universe, remains always the same

The foundation of this principle was laid by Newton in his Comments on the Third Law of Motion , but recent discoveries have raised it to the position of the grandest of known physical laws The statement of Newton may be thus translated —"When energy is expended on any system of bodies, it has its equivalent in work done against friction, molecular forces, or gravity, if there be no acceleration , but if there be acceleration, part of the energy expended is spent in overcoming the resistance due to the acceleration, and the additional kinetic energy developed is equivalent to the work so spent "

When part of the work is done against molecular forces, as in bending a spring, or, against the force of gravity, as in lifting a weight, the recoil of the spring and the fall of the weight are capable at any time of reproducing the energy originally expended The kinetic energy becomes potential But in Newton's day it was supposed that the energy spent in overcoming friction was absolutely lost , but Joule's investigations have proved that, in all such cases, a quantity of heat is generated which is an exact and definite equivalent for the kinetic energy lost Moreover, in every case in which energy is developed, it can be accounted for by the disappearance of an equal amount elsewhere. Hence it is concluded that if a part of the universe could be so isolated that it could neither receive energy from, nor give energy to, the parts of space external to it, then its total amount of energy would remain unchanged Further, if we consider

the motions of the molecules of matter which constitute light, heat, magnetism, and electricity, and the action of the forces due to chemical activity, as well as the motions and forces of which we are cognisant by direct observation, then we may state the law in its most universal form—namely, that the total amount of energy in the universe is the same at all times (See also *Energy*, and *Transmutation of Energy*

CONSTANT OF ABERRATION See *Aberration of the Celestial Bodies*.

CONSTELLATION (*Con*, together, and *stella*, a star) At a very early epoch astronomers seem to have recognised the necessity of assigning names to well marked star groups By associating these groups with the figures of men and animals to which they bore a more or less fanciful resemblance, the astronomer was able to refer readily to any definite region of the heavens Such an arrangement was especially useful when the path of a planet or comet was to be traced or recorded

It seems impossible to determine the real origin of the ancient constellations Undoubtedly those from whom we have received our accounts of the matter were not possessed of exact information on the subject, and the ancient zodiacs which have been discovered in Egypt, Assyria, and India, are too discordant to be readily interpreted The researches of Bryant and others throw some light on the mythological relations which form the basis of the distribution of the stars into constellations, but leave us altogether in the dark as to the epoch at which that distribution was effected, and as to the particular region of the heavens which each constellation covered. The subject is not indeed so trivial in its relation to astronomy as might be imagined at a first view If we could ascertain that a given group of stars exhibited at some far off epoch a real resemblance to the figure of bird, beast, or fish, whereas in recent times no such resemblance has existed, we should be led to the conclusion that over vast regions of celestial space there are in progress changes of inconceivable importance We learn that individual orbs have lost their lustre or grown brighter even during the past few centuries Were we quite sure of the real distribution of the stars into constellations in earlier ages, we might form conclusions of a similar nature with respect to whole systems of stars

When we consider the figures actually described by Aratus, and examine the regions of the heavens to which those figures are referred by him and others, we are impressed with the conviction that no resemblance whatever exists between the star groups and the creatures with which they are associated It may be worth while, however, to inquire whether the principle on which the ancient astronomers proceeded might not have been wholly different from that adopted by Eudoxus, Aratus, or Ptolemy The ancient astronomers may not have thought it by any means necessary that each constellation should be independent of the rest Where they recognised the figure of any object in a star-group, they might describe the group by that name, without regarding the circumstance that a portion, or even the whole of that group, belonged to some other constellation already recognised Precisely as the modern astronomer speaks of a certain part of the constellation Leo as the Sickle, so the ancients might speak of the Crown even though they regarded the stars forming that constellation as belonging to the uplifted arm of Bootes

Freeing ourselves from the considerations introduced by Ptolemy and others, it becomes possible to trace in the star-groups a real resemblance to many of the objects with which the fathers of the science of astronomy have associated them The figure of a lion can readily be traced, for example, in the stars forming the modern constellations, Leo Coma Berenices, Sextans, Leo Minor, the northern claw of Cancer, and the head of Hydra. Again, even Cancer, the least conspicuous of the ancient constellations, is accounted for when we recognise the crab's southern claw in the head of Hydra The poop of Argo can be recognised if the stars, forming the hind quarters of Canis Major be accepted as forming part of the ancient constellation

In this way a large part of the perplexity in which the subject of the constellations has hitherto been shrouded seems to be removed If we accepted the principle here advocated, we should find a natural interpretation of the ancient constellations in the simple fact, that the imaginative minds of the ancient astronomers found a real resemblance between certain star-groups and certain objects, and we might then safely reject all those fanciful methods by which Dupuis and others have endeavoured to interpret the ancient constellations

So far as modern astronomy is concerned, the subject of the constellations is an unsatisfactory one It seems impossible to free our star-maps and globes from the preposterous figures by which they are encumbered, and it has been indeed only of late years that astronomers have succeeded in checking the absurd practice of forming new constellations in which many modern map makers have indulged All that is at present to be hoped for is that by the gradual elimination of the smaller constellations still in vogue, simplicity may be restored to our globes and maps of the heavens But the only arrangement which would be really worthy of modern science, would be one according to which the heavens should be divided in a uniform manner,

founded on the existence on the celestial vault of a well-marked natural great circle, that, namely, about which the Milky Way pursues its course

The following list of constellations includes nearly all those which have been even temporarily adopted To distinguish those in present use from the rest, the former are printed in Roman, the latter in italic letters —

Constellations of Ptolemy

Northern

1 Ursa Minor, the Lesser Bear
2 Ursa Major, the Greater Bear
3 Draco, the Dragon
4 Cepheus
5 Bootes, the Herdsman
6 Corona Borealis, the Northern Crown
7 Hercules
8 Lyra, the Lyre
9 Cygnus, the Swan.
10 Cassiopeia
11 Perseus
12 Auriga
13 Ophiuchus or Serpentarius, the Serpent-bearer
14 Serpens, the Serpent
15 Sagitta, the Arrow
16 Delphinus, the Dolphin
17 Equuleus, the Little Horse
18 Pegasus, the Winged Horse
19 Andromeda
20 Triangulum Boreale, the Northern Triangle

Zodiacal.

21 Aries, the Ram
22 Taurus, the Bull
23 Gemini, the Twins
24 Cancer, the Crab
25 Leo, the Lion
26 Virgo, the Virgin
27 Libra, the Scales
28 Scorpio, the Scorpion.
29 Sagittarius, the Archer
30 Capricornus, the Sea goat.
31 Aquarius, the Water-bearer.
32 Pisces, the Fishes

Southern.

33 Cetus, the Whale
34 Orion
35 Eridanus, the River Eridanus
36 Lepus, the Hare
37 Canis Major, the Greater Dog
38 Canis Minor, the Lesser Dog
39 Argo, the Ship Argo
40 Hydra, the Water Serpent
41 Crater, the Cup
42 Corvus, the Crow
43 Centaurus, the Centaur
44 Lupus, the Wolf
45 Ara, the Altar
46 Corona Australis, the Southern Crown
47 Piscis Australis, the Southern Fish

Added by Tycho Brahe

1 *Antinous.*
2 Coma Berenices, the Hair of Berenice

Added by Hevelius

Northern

1 *Mons Mænalus*, the Mountain Mænalus
2 Canes Venatici (the Greyhounds, Asterion and Chara)
3 *Cerberus*
4 Lacerta, the Lizard
5 Lynx, the Lynx
6 *Scutum Sobieski*, the Shield of Sobieski
7 Sextans Uraniæ, Tycho's Sextant
8 *Triangulum Minus*, the Lesser Triangle
9 Camelopardalis, the Giraffe
10 Vulpecula et Anser, the Fox and Goose
11 Leo Minor, the Lesser Lion

Southern

12 Monoceros, the Unicorn
13 Sextans Uraniæ, Tycho's Sextant

Bayer's Southern Constellations

1 Indus, the Indian
2 Grus, the Crane
3 Phœnix, the Phœnix
4 *Apis*, the Bee (now Musca)
5 Pavo, the Peacock
6 Toucan, the American bird Toucan
7 Hydrus, the Water snake
8 Dorado the Sword fish
9 Piscis Volans, the Flying-fish
10 Chamæleon, the Chamæleon
11 Triangulum Australe, the Southern Triangle
12 Apus, the Bird of Paradise.

Lacaille's Southern Constellations

1 Apparatus Sculptoris, the Sculptor's workshop
2 Fornax Chemica, the Chemical Furnace
3 Horologium, the Clock
4 Reticulum Rhomboidale, the Rhomboidal Net
5 Cœla Sculptoris, the Graving Tools
6 Equus Pictorius, the Painter's Easel
7 *Pixis Nautica*, the Compass
8 Antlia Pneumatica, the Air-pump.
9 Octans, the Octant
10 Norma, the Square-rule
11 Circinus, the Compasses
12 Telescopium, the Telescope
13 Microscopium, the Microscope
14 Mons Mensæ, the Table Mountain

ROYER'S SOUTHERN CONSTELLATIONS

1 Crux Australis, the Southern Crown
2 Columba Noachi, Noah's Dove
3 *Nubis Major*, the Greater Cloud
4 *Nubis Minor*, the Lesser Cloud
5 *Fleur-de-lis*, the Lily of France

To these may be added contributions by Bode, Le Monnier, Poczobut, and others, including —

1 *Tarandus*, the Reindeer
2 *Solitarius*, the Hermit
3 *Taurus Poniatowskii*, Poniatowski's Bull
4 *Psalterium Georgianum*, George's Harp
5 *Honores Frederici*, the Honours of Frederic
6 *Sceptrum Brandenburgicum*, the Sceptre of Brandenburg
7 *Felis*, the Cat
8 *Lochium Funis*, the Logline
9 *Quadrans Muralis*, the Mural Quadrant
10 *Machina Electrica*, the Electrical Machine
11 *Officina Typographica*, the Printing Press
12 *Globus Aerostaticus*, the Balloon

It is difficult to understand what purpose the inventors of the constellations in the last list can have had in view in devising such absurdities The same remark applies, unfortunately, to many of the constellations still in use, especially to those invented by Hevelius and Lacaille It is a pity that the whims or the conceit of two or three astronomers should be suffered to disfigure our star maps, and that, apparently, there should be little hope of a change for the better

Francis Baily did good service in eliminating a few asterisms, and adopting for some of those he retained a more convenient nomenclature The following list of these changes is necessary to complete our account of the constellations —

Coma Berenices,	is written	*Coma*	Reticulum Rhomboidale,	is written	*Reticulum*
Vulpecula et Anser	"	*Vulpecula*	Fornax Chemica,	"	*Fornax*
Apparatus Sculptoris	"	*Sculptor*	Antlia Pneumatica,	"	*Antlia*
Cœla Sculptoris,	"	*Cælum*	Mons Mensæ,	"	*Mensa*
Equus Pictorius,	"	*Pictor*	Crux Australis,	"	*Crux*
Piscis Volans,	"	*Volans*			

He divides the constellation Argo, which is inconveniently large, into the four portions —

Malus, the Mast, Carina, the Keel,
Vela, the Sails, Puppis, the Stern

retaining the name Argo in the case of all stars which have had Greek letters assigned them, and using italics and Roman capitals for stars belonging to the sub divisions

Yet further changes of this sort might be adopted with advantage It is important that the name of each constellation should be as short as possible, because the arrangement of the star groups is interfered with when a long word has to be printed among the stars There seems no reason why the following changes should not be accepted —

For	Corona Borealis,	*Corona*	For Leo Minor,	*Leona*
"	Corona Australis,	*Corolla.*	" Vulpecula,	*Vulpes*
"	Ursa Major,	*Ursa*	" Equuleus,	*Equus*
"	Ursa Minor,	*Minor*	" Delphinus,	*Delphin*
"	Canis Major,	*Canis*	" Camelopardalis,	*Camelus*
"	Canis Minor,	*Felis*	" Monoceros,	*Cervus*

The constellation Sagitta seems also unworthy of the place it has in our maps

Under the titles of the principal constellations will be found remarks on their chief characteristics

CONTACT (*Contactus*, a touching) A term used in describing an eclipse of the sun or moon, or a transit of an inferior planet It is used to indicate the moment when the two limbs of the sun and moon just touch either interiorly or exteriorly in a solar eclipse, or when the outline of the earth's umbra or penumbra just touches the moon's limb, in a lunar eclipse, or lastly, when the limb of Venus or Mercury just touches the sun's, either exteriorly or interiorly, when a transit of either planet is in progress

CONTACT ACTION (See *Catalysis*)

CONTINUITY, LAW OF The principle that nothing passes from one state to another without passing through all intermediate states From this law, for instance, if it be known that at two instants of time a body had a temperature of 20°, and at another a temperature of 40°, then there must have been an instant between these, at which the temperature was 30°.

If a body, at two different times, had velocities of 12 feet and 20 feet per second, respectively, we may conclude, from the law of continuity, that between these times it had all velocities between 12 feet and 20 feet The principle is of considerable use in investigations on motion and physical change, it was distinctly laid down by Galileo, who ascribed it to Plato, but Leibnitz was the first to apply it extensively to test physical theories He established its truth by the method of *reductio ad absurdum* If a change were to happen without the lapse of time, the thing changed must be in two different conditions at the same instant, which is obviously impossible

CONTINUITY OF LIQUID AND GASEOUS STATES OF MATTER. See *Matter, Continuity of Liquid and Gaseous States of*

CONVECTION, DISCHARGE BY When an electrified insulated body is surrounded by a gas, the molecules of the gas coming in contact with it become charged, and then repelled, and thus carry away, by degrees, the electricity of the body This is called *discharge by convection* (See also *Discharge*)

CONVECTION OF HEAT (*Conveho*, to carry up) When a liquid is heated from above the temperature of the mass rises with extreme slowness, because liquids possess but little conducting power for heat, thus water may be boiled above ice, although separated from it by a very thin stratum of water But if the liquid be heated from below, and the ice be at the surface, a very different effect is observed, the ice melts quickly, and the whole mass of water is soon raised to the temperature of ebullition If amber dust or saw dust is diffused through a liquid which is being heated from below, we notice at once that currents of liquid ascend from the bottom to the top of the vessel, and the liquid acquires a uniform temperature This transport of heat by masses of matter is known as *convection* The layers of a liquid or gas which are nearest to the source of heat are expanded, and thus become specifically lighter than surrounding portions, consequently they rise, while colder, and consequently heavier, portions descend, are heated in their turn, and then ascend to make way for other colder portions. Thus, however badly a liquid or gas may conduct heat, it can rapidly acquire a uniform temperature by the convection of heat Now it is evident that the more expansible a body may be, the greater is its convective power, for the greater is the difference between the weight of equal bulks of cold and hot portions of it, consequently the movement of heated masses takes place with more facility and rapidity Hence convection takes place in gases far more readily than in fluids, because for equal increments of heat they expand to a greater extent than liquids It is obvious that convection cannot take place in solids, for mobility of particles is necessary before any displacement of masses can ensue, it also results that, other things being equal, convection takes place more readily in mobile than in viscid liquids, thus in glycerine or treacle the diffusion of heat through the mass would take place far more slowly than in water or alcohol The displacement of the lighter warm layers of a liquid or gas, by heavier and colder layers, is due to gravity Dr Balfour Stewart has well remarked, "Were there no gravity there would be no convection, indeed, the very term *specifically heavier* has a reference to gravity so that if this force did not exist it would be a matter of no consequence what part of a vessel of water we heated, the effect of the heating would be always the same"

In nature we have many notable examples of the convection of heat, and some of these are on a gigantic scale, we need do no more than refer to the trade-winds, and various great ocean currents in exemplification of this The gradual cooling of a mass of water, until it has attained its maximum density (see *Maximum Density of Water*), is another example of convection (See also *Winds, Climate*)

CONVERGING RAYS are those which, proceeding from several points, meet together in one point, which is called the *focus* or *focal point*

CONVEX LENS, DOUBLE A lens formed of two spherical surfaces, each curved outwards An equally convex lens has the radii of its two surfaces equal, an unequally convex lens has them unequal Convex lenses converge parallel rays of light to a focus

CONVEX MIRROR (*Convexus, conveho, con*, together, and *veho*, to carry) A reflecting surface of a convex form It renders parallel rays falling upon it divergent, seeming to radiate from a point behind it called the virtual focus This point is about one-half the radius of convexity behind the mirror Images reflected from convex mirrors appear much smaller than their real size, and more distant (See *Mirror*)

COOLING, VELOCITY OF If we pass from the warm outside air of a summer day into an ice house or cold vault we find ourselves chilled, because, in accordance with Prevost's theory of exchanges, (which see), our bodies part with more heat than they receive when surrounded by objects possessing a lower temperature than their own It is a case of uncompensated radiation, and the velocity of cooling increases, as the difference of temperature between the surrounding medium and the cooling bodies is greater. The first complete and

accurate experiments on the cooling of bodies were made by Dulong and Petit, and were communicated to, and crowned by, the *Académie des Sciences* in 1818 The mode of experiment was to enclose a very large thermometer, the mercury in which possessed a known temperature in a hollow sphere of copper blackened inside, in such a manner that the centre of the bulb of the thermometer and of the copper sphere coincided By placing the sphere in water of different temperatures, a uniform temperature could obviously be established within it The temperature of the mercury in the thermometer was higher than that of the sphere, and the velocity of cooling was indicated by the number of degrees through which the mercury fell in one minute of time

The following results, as stated by Pouillet, were obtained by Dulong and Petit by this method of experimenting The copper sphere was 30 centimetres (11 78 inches) diameter, and the thermometer contained between 2 and 3 lbs of mercury, and was provided with a long and accurately graduated stem

VELOCITY OF COOLING

Excess of temperature of the thermometer	Temperatures of the enclosure				
	0° C	20° C	40° C	60° C	80° C
240° C	10 69	12 40	14 35		
220	8 81	10 41	11 98		
200	7 40	8 58	10 01	11 64	13 15
180	6 10	7 04	8 20	9 55	11 05
160	4 89	5 67	6 61	7 68	8 95
140	3 88	4 57	5 32	6 14	7 19
120	3 02	3 56	4 15	4 84	5 64
100	2 30	2 74	3 16	3 68	4 29
80	1 74	1 99	2 50	2 73	3 18
60		1 40	1 62	1 88	2 17

From these results the following law was deduced —The velocity of cooling in a vacuum increases in geometrical progression if the temperature of the enclosure increases in arithmetical progression, for the same excess of temperature

The above table shows us that the velocity of cooling increases with the temperature of the enclosure, when the excess of temperature of the cooling body is constant thus a thermometer at 200° C cools faster in an enclosure possessing a temperature of 100° C than a thermometer at 100° C in an enclosure possessing a temperature of 0° C, the excess of temperature of the thermometer above the enclosure being in both cases the same

COPERNICAN SYSTEM The system by which Copernicus explained the apparent motions of the planets According to this system the sun occupies the centre of the system, and all the planets travel around him, those nearer to him travelling more swiftly than those farther from him Copernicus was unable to pronounce definitely as to the figure of the planetary orbits He saw that they were not circles having the sun as centre, and he was disposed to adopt some of the Ptolemaic contrivances of epicycles and eccentrics to account for the observed peculiarities of planetary motion (See *Keplerian System*) The great merit of his system consists not in any extreme simplicity of the motions he ascribed to the planets, but in the orderly arrangement of the planetary scheme in subordination to the sun as the orb around which all the main motions were performed In the *Ptolemaic System* (*q v*) it was necessary to conceive first of the motion of imaginary points around the earth, and then of equally extensive motions of the planets around these moving points It need hardly be added that in explaining the apparent motions of the planets, their advances, stations, and retrogressions, as due to real motions about the sun as centre, Copernicus at the same time taught that the diurnal motion of the heavens is only apparent, and due to a real motion of the earth upon her axis

COPPER An elementary metallic substance known to the ancients, its Latin name, *Cuprum*, is derived from Cyprium, as the Romans first obtained it from the Island of Cyprus, and called it *Æs Cyprium*, (Cyprian brass), this was soon contracted to Cuprum From this word the symbol Cu is obtained. Atomic weight, 63 5 Specific gravity between 8 91 and 8 95 Specific heat, 0 09515 between 0° and 100° C (32° and 212° F) Melting point between that of gold and silver, being somewhere about 2300° F It expands on solidifying Next to silver it is the best conductor of electricity, being in the pure state 93 08, while silver is 100 It is very hard, elastic, and tough, possesses great malleability and ductility, and it

crystallises in the regular system, forming cubes, octahedrons, and rhombic dodecahedrons. It occurs native in many parts of the world, the principal deposits being on the coast of Lake Superior, one mass having been found there weighing 500 tons. The principal ores of copper, besides the native metal, are the *sulphides of copper*, either alone or in combination with other metals, such as *copper glance* (Cu_2S), *Indigo copper* (CuS), *copper pyrites* (Cu_2S, Fe_2S_3), *variegated copper ore* ($3Cu_2S, Fe_2S_3$), *Fahl ores* containing variable admixtures of sulphides of copper, iron, zinc, silver, mercury, antimony, and arsenic, *Enargite*, containing sulphides of copper and arsenic. *oxidised copper ores*, such as red copper (Cu_2O) and black oxide of copper, and *copper salts*, such as malachite (which is carbonate of copper), silicate of copper, dioptase, chloride of copper, atacamite, phosphate of copper, and arseniate of copper. Copper is extracted commercially from all these ores, it is also found in minute quantities in most soils, in sea weed, in many vegetable products, and in the animal body. Copper smelting is not a complicated operation when ores are used which do not contain sulphur, reduction readily taking place at a high temperature in the presence of charcoal, and a suitable silicious flux. When, however, sulphur is present, a more complicated operation has to be adopted, the object being to remove the iron and other metals in the form of silicate in the slag, and concentrate the copper into a fusible sulphide. After this operation has been repeated two or three times, a regulus of almost pure sulphide of copper is obtained. This is roasted with free access of air, when most of the sulphur passes off as sulphurous acid, and the copper oxidises. At a certain stage of the process the remaining sulphide of copper and oxide of copper react upon each other, forming sulphurous acid, and metallic copper in an impure state, known as coarse copper, blister copper, and black copper. This metal is then submitted to refining, which is effected principally by exposing it in a melted state to the action of air and a highly silicious slag, until the impurities have passed into the slag. In this state the copper is what is technically called *dry*, containing oxide of copper dissolved in it. To remove this, charcoal or anthracite is thrown upon the melted surface, and the metal is then stirred up with a green wooden pole. Violent commotion takes place, and the oxide is reduced to the metallic state. If this *poling* is not carried on sufficiently long the copper is termed *underpoled*, whilst if it goes on too long it becomes *overpoled*, and carbon gets into the copper, the remedy for this is to allow the air to act upon the surface for a short time. During these operations the smelter removes samples from time to time, and tests them by hammering. As soon as the metal is of *tough pitch*, it is ladled into moulds. Copper is sometimes extracted in the wet way from drainage waters of mines and other solutions containing this metal, it is precipitated by metallic iron, and the resulting spongy copper melted and refined. Copper tarnishes slightly in the air, its principal solvent is nitric acid, which attacks it violently, forming nitrate of copper, it unites with chlorine at the ordinary temperature, forming chloride of copper, and at a high temperature with bromine, iodine, and sulphur, and most of the metals. For a description of the salts of copper see under the headings of the respective acids and for the principal alloys of copper see *Alloys*.

Copper forms two oxides, the *protoxide* (CuO), and the *suboxide* (Cu_2O). The protoxide is found native in dark steel gray crystals, possessing a specific gravity of 5 9. It is prepared artificially by heating copper in contact with air, or by igniting the sulphate, carbonate, or nitrate of copper. It is also prepared in the wet way by adding caustic potash to a hot solution of a cupric salt, thus formed, it is a black powder which melts at a red heat. The suboxide of copper occurs native in red translucent crystals, having a specific gravity of 5 8, prepared artificially it forms a beautiful crimson powder. Both these oxides are easily reduced to the metallic state by heating with reducing agents. *Proto chloride of copper* is brown in the anhydrous state, and green when hydrated, it is very soluble in water, forming a beautiful emerald green solution when concentrated, but pale blue when dilute. There are several *sulphides of copper*, the principal being the *proto-sulphide* and the *di sulphide*, corresponding in composition to the two oxides. They are both found native, and are worked as copper ores, the proto sulphide is often formed in analytical operations, in the process of separating copper from other metals, it is thrown down as a dark brown precipitate, insoluble in water and cold acids.

COPPER PYRITES. See *Copper*.

COPPERAS. See *Sulphates, Iron*.

COR CAROLI (Charles's Heart). The star α of the constellation Canes Venatici, or Catuli.

COR HYDRA (The Heart of the Sea Snake). The star α of the constellation Hydra. It is also called Alphard, or the Solitary One.

COR LEONIS (The Lion's Heart). The star α of the constellation Leo. It is also called Regulus.

CORNEA (*Cornu*, a horn.) The transparent horny membrane which covers the front part of the eye. (See *Eye*.)

CORONA, SOLAR In astronomy this term is applied to the glory of light seen around the totally eclipsed sun This phenomenon has attracted much attention, and many theories have been hazarded as to its real nature Halley was disposed to regard it as due to the existence of a lunar atmosphere, an idea which Newton rejected, and which has since been thoroughly disproved We now know that if the moon has an atmosphere at all it is one of very small extent Delisle and others have suggested that the phenomenon may be due to the diffraction of the sun's light in passing tangentially by the moon's sphere Although this theory seems supported by experimental tests, it has been shown by Sir David Brewster to be untenable, since any diffraction ring thus occasioned would necessarily be too narrow to be visible from the earth In recent times a theory has been put forward which ascribes the corona to the glare of light in our own atmosphere, but no evidence has been given to show how this glare can be produced, or that it would account for the special characteristics of the coronal light The theory, in fact, will not bear examination

There remains only the conclusion that the corona is a true solar appendage, though of what nature has not yet been clearly shown From the observations made by Mr Lockyer in the spectrum of the prominences, that ingenious observer has been led to conclude that the corona cannot be a solar atmosphere Dr Frankland's observations of the spectrum of hydrogen show that at the bottom of such an atmosphere the hydrogen of the prominences could not fail to give a different spectrum than that seen by Mr Lockyer It would appear clear therefore that the particles forming the corona must be prevented from pressing towards the sun by their own motions Thus the conclusion is suggested that they are in reality members of those meteoric systems whose perihelia must exist in countless thousands in the sun's neighbourhood. Baxendell of Manchester has shown from meteorological considerations that there probably exists round the sun an envelope of some such nature Leverrier also has shown that the motions of Mercury indicate the existence of bodies (whose combined mass must be considerable) travelling within the orbit of Mercury

CORONA AUSTRALIS (The Southern Crown) One of Ptolemy's southern constellations The stars forming this constellation are chiefly remarkable as defining part of the limits of a region rich in stars, the region immediately beyond towards the north being singularly barren, so far at least as lucid stars are in question

CORONA BOREALIS (The Northern Crown) One of Ptolemy's northern constellations It was within this constellation that in May 1869 a star blazed suddenly forth, attaining at once the brilliancy of a second magnitude star This orb appeared in the place formerly occupied by a star of the tenth magnitude, so as to suggest the conclusion that through some unknown cause this minute star had suddenly been lifted up with new splendours Examined by Mr Huggins with the spectroscope, the light of the new star told a strange story There was the usual continuous spectrum, but across this spectrum there were the bright lines corresponding to glowing hydrogen, so as to justify the inference that there had been an outburst of hydrogen flames over the surface of this distant orb Whether a sun had thus suddenly acquired a lustre exceeding several hundredfold its former brilliancy may indeed be gravely questioned Far more probably the new star was relatively minute. It is noteworthy that until the appearance of this temporary brilliant, all the phenomena of the same character had made their appearance on the borders of the Milky Way It is worth considering whether this exception should lead us to forget the rule which has characterised all other instances

CORONA, SPECTRUM OF THE During the total solar eclipse of August 1869, Prof Young found that the corona, instead of showing a subdued solar spectrum, yielded a spectrum of three bright green lines From the close accordance between these coronal lines and three of the auroral lines, he considers that there is a relationship between the corona and the aurora. (See *Spectrum*, *Aurora Borealis, Spectrum of*)

CORNISH BOILER See *Steam-Boiler*

CORPUSCULAR THEORY OF LIGHT There are two theories of light—the *Undulatory* or *Vibratory Theory*, and the *Corpuscular* or *Emissive Theory* According to the latter, light consists of an emanation of excessively minute particles of matter, projected from the sun and other luminous sources with an enormous velocity This theory which was advocated by Newton, is now universally superseded by the undulatory theory (See *Undulatory Theory of Light*)

CORRELATION OF ELECTRICITY (See *Electricity, Correlation of*)

CORRELATION OF THE PHYSICAL FORCES The principle that any one of the various forms of physical force may be converted into one or more of the other forms The term is due to Mr Grove who thus explains the doctrine to which it was applied "The various affections of matter which constitute the main objects of experimental physics, namely,

heat, light, electricity, magnetism, chemical affinity, and motion, are all correlative, or have a reciprocal dependence, that neither, taken abstractedly, can be said to be the essential cause of the others, but that either can produce or be convertible into any of the others Thus heat may mediately or immediately produce electricty, electricity may produce heat, and so of the rest, each merging itself as the force it produces becomes developed, and that the same must hold good of other forces, it being an irresistible inference from observed phenomena that a force cannot originate otherwise than by devolution from pre-existing force or forces" It is now generally admitted that the term "Transmutation" more accurately describes this relationship (See *Transmutation of Energy*)

CORRECTION FOR CAPILLARITY See *Barometer*

CORROSIVE SUBLIMATE See *Mercury, Chlorides*

COR SCORPII, or, *Cor Scorpionis* The *Scorpion's Heart* The star α of the Constellation Scorpio (See *Scorpio*) It is also called *Antares*

CORUNDUM Pure alumina in the native crystalline state The sapphire, ruby, oriental amethyst, and oriental topaz, are called precious corundum, being crystallised alumina tinged with some colouring matter, whilst adamantine spar and emery are called common corundum Its hardness is next to that of the diamond, being nine on the scale, specific gravity about 4 0 It is infusible before the blow-pipe, and insoluble in acids, it is somewhat brittle and has a conchoidal fracture The precious varieties are transparent, and the common variety translucent or opaque

CORVUS (The *Crow*) One of Ptolemy's Southern constellations It consists of a group of stars near Hydra, and is by some astronomers regarded as a portion of that constellation The figure of the group somewhat resembles that of a crow, but not in the attitude usually depicted on maps and charts The head should be near the star Eta, not near Alpha

COSMICAL (κοσμικός) A term used by ancient astronomers When a star rose at the same time as the sun, it was said to rise *cosmically* So the cosmical setting of a star signified the coincidence of its hour of setting with that of the sun See *Acronycal, Heliacal*

COUPLES (*Copula*, a link) Two equal parallel forces acting on a body in opposite directions form what is known as a *couple* It is evident that such a combination can only cause the body to rotate A railway turn-table supplies an illustration If equal forces be applied at each extremity of the same diameter in opposite directions, the turn table is caused to rotate about its centre, together with the engine or carriage placed upon it, and it is obvious that in such a case no motion of translation could take place if the turn-table were free to move The perpendicular distance between the directions of the forces, is called the *arm* of the couple, and the perpendicular to the plane of the couple at the middle point of the arm is termed the *axis* of the couple Referring again to the turn-table, suppose equal forces applied first at a certain distance from the centre, and then the same forces applied at double the distance, the effect of the couple in the second case would be twice that in the first Now suppose the points of application to remain the same, but the intensity of the forces to be doubled, the effect of the couple will again be doubled, and if the forces are doubled, and also the distance of their points of application from the centre, the effect of the couple is quadrupled This product of the distance of the point of application by the intensity of the forces is called the moment of the couple, and, generally, the effect of the couple is measured by the moments of the forces about the axis, and so long as the moment remains the same, no change in the couple alters its effect The chief laws of couples are, first, that if points be taken either in the arm of the couple, or without the couple but in its plane, the moment of the couple about all such points remains constant, secondly, that two couples are equivalent to one another when their moments are equal From these are deduced, as subsidiary laws, (1) A couple may be turned in its own plane through any angle, at any point in its arm, without altering its effect (for the moment about the axis is not thereby changed), (2) A couple is not altered by being moved parallel to itself, (3) Two couples are equivalent if their moments are equal and they act in the same direction A couple cannot have a single force as its resultant, and consequently a single force can never counteract the effect of a couple But a number of couples may have a resultant couple possessing the combined effect of all the couples If the couples act in the same plane or in parallel planes, their resultant is a couple, whose moment is the sum of the moments of the couples, but if they are in planes which intersect, the resultant couple may be found by the parallelogram of couples, a method analogous to the parallelogram of forces As a general fact, the laws of the composition and resolution of couples are similar to the corresponding laws of single forces, the axis of the couple corresponding to the direction of the force, and the moment of the couple to the magnitude of the force

COUPLING In machinery any contrivance for connecting permanently or occasionally the different moving parts of a machine. The term is applied more particularly to the parts

rming the longitudinal connections of the shafts (See Buchanan's *Practical Essays on Mill Work*)

COURONNE DE TASSES See *Crown of Cups*

CRAB A machine used by builders and others for raising weights It consists of a orizontal axle with a large toothed wheel usually turned by a winch and a small toothed wheel The rope or chain wound round the axle may be made to pass in any direction, as or instance so as to raise weights vertically, by a suitable arrangement of pulleys

CRANE A compound machine, used for raising heavy weights, and at the same time removing them some distance from the place from which they were taken, as for instance for raising goods from the hold of a ship and removing them to the quay The crane usually onsists of a wheel and axle fixed to a vertical shaft or arbor, and a pulley attached to the end f a projecting arm The shaft rests on a pivot at the lower extremity, and is supported in the middle by a metal ring let into a block of stone into which works a set of wheels called friction ollers The arm or jib is fixed to the upper extremity of the shaft, usually at an angle of bout 45° The weight or load is attached to a chain which passes over the pulley at the end f the jib, and then round the axle On turning the winch the weight is raised as far as ecessary, and the whole machine is then turned on the pivot until the weight is directly over he place at which it is to be deposited, where it is allowed gently to descend Steam cranes re now in common use

CRANK (Dutch, *kring*, a circle) An important contrivance in the process of converting rectilinear motion, as that of the piston in a steam engine, into a motion of rotation It consists usually of a double winch, but sometimes is only single The part between the two elbow oints is termed the arm of the crank The connecting rod which transmits the alternate otion due to the power is attached to the crank by a joint, and consequently is made to raverse the circumference of a circle of which the arm is the radius, and so to produce the otation of the axis The connecting rod has its greatest effect in turning the crank about its xis only when it is at right angles to the arms, and in every other position, a portion of its orce spent in pulling the crank away from the axle When the connecting rod is in a traight line with the crank (which occurs twice in every revolution) it has no tendency whatver to turn the crank and the axle These are called the "dead points" of a machine, and were it not for the momentum acquired by the heavy parts of the machine, the motion would case at these points As it is, the motion must be greatly retarded at the dead points, and orrespondingly increased at the points of greatest action, if no other method of equalising the motion were available. The variations of speed resulting from the alternating action of the iston rod are brought within very narrow limits by the use of the fly-wheel (See *Fly wheel*)

CRATER (The *Cup*) One of Ptolemy's northern constellations It is situated near orvus, and, like that constellation, is by some regarded as a part of the constellation Hydra. he star Alpha Crateris has greatly decreased in magnitude since Bayer's time

CREAM OF TARTAR See *Tartaric Acid*

CREATINE (κρέας, flesh) An organic base obtained from the juice of flesh In the ydrated condition it forms clear prismatic crystals of the formula $C_4H_9N_3O_2\ H_2O$, which issolve in 74 6 parts of water at 64 F, and are very soluble in boiling water Strong acids onvert creatine into creatinine by abstraction of the elements of water

CREATININE One of the normal constituents of urine Like urea it is supposed to be a roduct of oxidation, its quantity is increased by animal food (See *Creatin*, *Animal Nutrition*)

CREOSOTE (κρέας, flesh, and σώζειν, to preserve) A highly antiseptic liquid of a trong penetrating odour and burning taste Specific gravity 1 37 Boiling point, 203° C. 397 F) Formula, $C_8H_{10}O_2$ Commercial creosote is frequently impure carbolic acid from oal tar, but true creosote is a distinct body, and is obtained in the distillation of wood by somewhat complicated process It is largely used as an antiseptic, and to prevent decomposition of animal matter, and it is to this substance that wood-vinegar and wood smoke owe heir preservative properties

CRESYLIC ALCOHOL An oily liquid extracted from coal tar, homologous with phenylic lcohol or carbolic acid Most of the impure liquid carbolic acid of commerce really consists of resylic alcohol, and as such it is used in enormous quantities for antiseptic and disinfecting urposes Formula, C_7H_8O It is a colourless strongly refracting liquid, boiling at 203° C 397 F) slightly soluble in water, and miscible in all proper proportions with alcohol and ether

CRITICAL POINT OF TEMPERATURE See *Matter, Continuity of Liquid and Gaseous States of*

CROWBAR (So called from the end of the bar being sharpened like a crow's beak) A traight lever of the first kind used by workmen to raise heavy weights, stones, &c The

fulcrum is the stone or block placed at a short distance from the end to support the lever, the weight is the stone to be lifted, and is placed at the end near the fulcrum, the power is the manual force applied at the other end of the bar The mechanical advantage of the crowbar depends on the distance between the hand and the fulcrum compared with the distance between the weight and the fulcrum (See *Lever*)

CROWN OF CUPS, or, *Couronne de Tasses* A simple form of battery invented by Volta It consists of a series of plates of copper and zinc placed in dilute sulphuric acid, the copper of one being connected with the zinc of the next and so on The cells were made small and arranged in a circle, so that the extremities of the chain were brought near to each other, hence the name On connecting the first copper with the last zinc, by means of a wire, a current, according to our conventional language, passes from the copper through the wire to the zinc The apparatus has little more than historical interest, better forms of battery having been since constructed, and even in the case of using copper and zinc elements the plates and cells are made very much larger than those of Volta's crown of cups

CROWN WHEEL The teeth of the crown wheel are set parallel to its axis, and at right angles to the rim, so as to appear on the *crown* of the wheel, and being made of suitable size they work readily in the teeth of an ordinary spur wheel, having its axis at right angles to that of the crown wheel It is the usual method adopted in clock work when transformation of motion to the extent of 90° is required (See *Horology*, *Bevelled Wheel*)

CRUX (Abbreviated for Crux Australis, the *Southern Cross*) A southern constellation devised by Royer Its four principal stars form a cross, though they are considerably unequal in magnitude The upright of the cross points to the southern pole, where, however, there is no conspicuous pole-star Within the constellation Crux is the singular vacuity in the Milky Way, known as the Coalsack This vacuity is not only free from the stars forming the Milky Light of the Galaxy, but also from lucid stars Within its range, however, many telescopic stars can be detected

CRYOPHORUS (κρύος, ice, and φέρω, to bear) An instrument invented by Dr Wollaston (see *Philosophical Transactions* for 1813), for showing the cold produced by evaporation It consists of two glass bulbs, usually $1\frac{1}{2}$ to 2 inches diameter, united by a tube one or two feet long, bent at a right angle at each end for two or three inches of its length One of the bulbs is half filled with water, which is boiled until all the air has been expelled from the instrument, through a small hole at the opposite extremity, which is then hermetically sealed We have now, therefore, a mass of water in a vacuum containing aqueous vapour given off from the water The empty bulb is placed in a beaker and surrounded by a freezing mixture of ice and salt, which condenses the aqueous vapour in the bulb into water, and fresh vapour is supplied by the water in the distant bulb, ultimately this water is frozen The instrument for this reason has received the name of *ice bearer*, or *carrier of cold* We know that heat determines the form in which matter exists (see *Expansion*), and that a gas is a liquid *plus* heat, and therefore requires heat for its production Now, in the cryophorus we have a certain amount of aqueous vapour, the pressure of which upon the water in the distant bulb prevents further evaporation, in fact the vacuum is saturated, but when the vapour is condensed by the freezing mixture, the pressure disappears and the water emits its vapour into the resulting vacuum, and thereby loses heat, since the water requires heat before it can become vapour, when this vapour is condensed a further quantity is supplied by the water which is still more chilled, and this action continues until it is frozen by its own evaporation (See also *Evaporation*)

CRYSTALLINE HUMOUR The contents of the *crystalline lens* of the eye is called the *crystalline humour* (See *Eye*)

CRYSTALLINE LENS (κρυσταλλος, ice) The lens of the eye containing the crystalline humour (See *Eye*)

CRYSTALLISATION, ACTION OF LIGHT ON When a saline solution contained in a glass dish is set aside to crystallise, the crystals form first on the side nearest to or most exposed to the light So also camphor, iodine, napthalin, chloride of carbon, &c, which form vapour by spontaneous sublimation, deposit crystals on the side of the glass most exposed to the light Water and other liquids deposit globules of moisture generally on the most illuminated side of the vessels containing them In the vacuum of a barometer, vapour of mercury similarly condenses on the side most exposed to light Hence it was long supposed that light exerted some subtle action in promoting crystallisation, &c, until Mr Tomlinson showed (*Phil Mag*, Nov 1862) that these deposits are due simply to differences in temperature The side of the vessel most exposed to the light is generally the coldest, and hence it was natural to suppose that light and not heat was the efficient cause, but Mr Tomlinson showed that similar effects could be produced in the dark, provided one part of the vessel were made colder than the other, or in the full light of day, and even in sunshine, when the apparatus was so arranged that one

part of each vessel had a different temperature as compared with another part The same cause which produces dew also accounts for the phenomena in question

CRYSTALLOGRAPHY. Almost all solid chemical compounds when slowly formed, assume a regular shape, bounded by plane surfaces The science of crystallography treats of the laws by which these surfaces are disposed one to the other Crystals are assumed to possess certain axes, and the form is determined by the relation which the plane surfaces bear to these axes Although the forms in which bodies crystallise are almost infinitely varied, it has been found that they may be classified into seven crystallographic systems These are briefly as follows —

1 The *regular cubic or monometric system* —These crystals are symmetrical about three rectangular axes, the simplest forms are the cube and regular octahedron The following substances crystallise in this system—diamond, most metals, chloride of sodium, fluorspar, alum

2 The *quadratic or dimetric system* —These crystals are symmetrical about three axes, which are rectangular, but only two of equal length, the third being different Amongst the substances which crystallise in this system, may be mentioned sulphate of nickel, tungstate of lead, and double chloride of potassium and copper

3 *Hexagonal or rhombohedral system* —In this system the crystals possess four axes, three being equal in length, situated in one plane, and inclined 60° to one another, and a principal axis at right angles to the plane of the former Amongst crystals of this system may be mentioned quartz, beryl, and calcspar

4 *Rhombic or trimetric system* —These crystals have three rectangular axes all of different lengths Amongst crystals of this form may be mentioned sulphate of potassium, nitrate of potassium, sulphate of barium, and sulphate of magnesium

5 *Oblique prismatic or monoclinic* —These have two axes obliquely inclined, and a third at right angles to the plane of these two, all three being unequal Amongst crystals of this form may be mentioned ferrous sulphate, sugar, gypsum, and tartaric acid

6 *Diclinic system* —In this there are two axes at right angles, and a third oblique to the plane of these two, the primary form being a symmetrical eight sided pyramid

7 *Doubly-oblique prismatic or triclinic* —In this system the three axes are all inclined obliquely, and of unequal length Amongst crystals of this form may be mentioned sulphate of copper

Crystals frequently cleave much more easily in one direction than in another, thus mica may be divided into laminæ by the fingers, calcspar breaks up into rhombs by a blow with the hammer, and galena in a similar manner into cubes The diamond is frequently divided by placing a sharp steel edge along its line of cleavage, and tapping sharply with a hammer The angles of crystals are measured by an instrument called a *Goniometer*, which see

CRYSTALLOID See *Dialysis*

CRYSTALS, COLOURED RINGS IN When a slice of a double refracting crystal, cut at right angles to its optic axis, is examined in the polariscope, a system of coloured rings are observed, surrounding a black cross in one position of the analyser, which changes to a white cross in another position The rings are circular in uni axial crystals, and more or less elliptical in biaxial crystals (See *Polariscope*, *Polarisation*)

CRYSTALS, DICHROIC See *Dichroic Crystals*

CRYSTALS, DOUBLE REFRACTION OF Many crystals possess the power of double refraction—that is, of dividing a ray of common light into its two component rays oppositely polarised These two rays traverse the crystal with different velocities and in different directions Crystals of Iceland spar or calcspar possess this property in a very high degree, and are frequently employed in optical research (See *Polarisation of Light*, *Polarisation by Double Refraction*) This property is not possessed by all crystals, some have only single refraction, and act like an ordinary transparent medium

CRYSTALS, OPTIC AXES OF See *Optic Axes of Crystals*

CUBIC NITRE See *Nitrates, Nitrate of Sodium*

CULMINATION (*Culmen*, the summit) The passage of a heavenly body across the celestial meridian We sometimes meet with the expression meridional culmination It is, however, incorrect, as the culmination of a heavenly body is necessarily meridional

CUMULUS (A heap) A form of cloud (See *Cloud*)

CUPELLATION A method of separating silver or gold from lead Owing to its easy fusibility, and the ready way in which it unites with these precious metals, lead and its compounds are frequently smelted with substances containing small portions of gold and silver, when the reduced lead unites with and carries down with it these metals This affords a method of accumulating all the gold or silver into a button of lead, and the cupellation process is then adopted to effect the further separation It may be carried out on a very large scale, as in lead-works, where the cupels are several feet in diameter, and sometimes contain cakes

of silver weighing many thousand ounces, or it is employed, on the small scale, for assay purposes, in which case the cupels are from 1 to 2 inches in diameter, and the resulting bead of silver or gold sometimes does not weigh more than a minute fraction of a grain In either case, however, the principle is the same The cupel, as the vessel is termed in which the operation is effected, is a very thick but shallow basin, made of bone ash, beaten up with water, and dried This forms a very porous absorbent material, which sucks up melted oxide of lead in the same way that blotting paper will suck up water, whilst it has no absorbent powers for melted metals The cupel is heated in a furnace to full redness, and the lead is put in it, being protected by an arched clay cover from the action of the smoke or furnace gases, whilst, at the same time, a strong current of air passes over its surface The heat is raised to such an extent that the lead not only melts, but the oxide which rapidly forms on its surface likewise melts and is absorbed by the body of the cupel, thus constantly exposing a clean surface to the action of the air The metallic button rapidly diminishes in size, the lead being absorbed into the cupel, whilst the precious metal remains unaffected, until ultimately the whole of the lead is removed, and nothing is left but a button of pure gold or silver On the large scale, and sometimes also in assay operations, an absorbent cupel of bone ash is not used, but what is termed a scorifier is employed instead This is a non-absorbent clay vessel, and the oxide of lead as it forms is allowed to accumulate, until it runs off through a channel at one side, or it is removed by other means

CURRENT, ELECTRIC To explain what is meant by an electric current, let us suppose a wire connected with the ground to be applied to the prime conductor of an electric machine while it is being worked The prime conductor is thus discharged, and according to common phraseology, the electricity passes through the wire to the ground This passage of the electricity is called an *electric current*, and it is found that during the passage of the electricity the wire acquires certain temporary properties which are said to be due to the electric current There are other ways of producing an electric current besides that just mentioned Thus, if a plate of zinc and a plate of copper be partially immersed in dilute sulphuric acid without touching each other or any conductor, the copper will be found positively electrified, and the zinc will be found negatively electrified, and on connecting them by means of a wire, discharge or passage of electricity through the wire will take place, and will be kept up as long as the zinc and sulphuric acid are not used up by chemical action The wire connecting the copper and zinc is found to have the very same properties as the wire connecting the prime conductor and the ground We say then that a current is passing through it, and by convention we say that the current takes place from a positive place to a negative, that is, in this instance, from the copper through the connecting wire to the zinc We can only refer here to the general properties of an electric current and to the sources of currents, and indicate where detailed information on the various points may be found

The most important property which an electric current has, is perhaps its effect upon a magnetised needle suspended in its vicinity, since it is generally by means of this action that the existence of a current is detected, and its strength measured When a magnetised needle is suspended so as to be capable of turning about an axis perpendicular to its length, as is the case with a common compass needle, and is brought near to a wire through which a current is passing, the needle tends to turn its length at right angles to the direction of the current If, then, the current be flowing in the north and south direction, and if the needle is suspended so as to be influenced by the earth, the current will tend to turn it east and west, the earth to turn it north and south, and the position of equilibrium will depend upon the power of the current compared with the directive force of the earth's magnetism It is upon this principle that the *galvanometer* or current measurer is founded Again, if there be two wires near to each other, each of them conducting a current, and one or both able to turn about an axis at right angles to the direction of the current, the wires will place themselves so that the directions of the currents are parallel to each other, and when in this position they will exert upon each other an attractive force The action of currents upon magnets and of currents on currents is fully discussed under *Electro dynamics* and *Electro-magnetism*

The properties of currents with respect to the conductors which carry them are, perhaps, next in importance As is explained under *Conductor* and *Resistance*, there are very marked differences in the powers which various substances have of transmitting a current proceeding from a given source There are some bodies which will scarcely permit it to pass at all, others which permit it to pass very freely, and between these extremes substances offering every grade of resistance great and small to the passage of it Again, in the same substance the conduction depends very much upon the dimensions of the conductor. A long wire offers much more resistance than a short one, and a thin wire much more than a thick one The effect of the resistance of the conductor is to diminish the strength of the current, that is, the quantity

f electricity which passes in a given time Thus, taking the same battery and introducing ires of different resisting powers, it is found that the whole action is diminished in proportion o the resistance introduced The resisting of the current at one part of the circuit diminishes it t all parts, for the law holds that, at any one time, the same quantity of electricity is passing hrough every section of the circuit Resistance to the current gives rise to heat at the place where the resistance takes place Thus, if a fine platinum wire be inserted between the two oles of the battery, it may easily be heated to red or white heat, or even to the melting temperature The amount of heat developed depends upon the resistance offered, and is simply proportional to it It is also proportional to the square of the strength of the current Some urther remarks upon this point will be found under *Electricity, Correlation of, Current, Heating Effects of*

We now turn to the chemical effects of the electric current, mentioning merely the general laws, and reserving the full discussion of the subject for our article on *Electrolysis* When a current is passed through a conducting liquid containing a salt, it in general decomposes the salt, breaking it up into two portions, one of which goes to the place at which the current enters the liquid, the other to that at which it leaves it The metal of the salt, or what corresponds to it, goes to the latter, the halogen, or what corresponds to it, goes to the other Thus iodide of potassium breaks up into potassium and iodine, the potassium goes to the side which is connected with the zinc end of the pile or battery, the iodine to that which is connected with the copper end The amount of decomposition which takes place in a given time, is proportional to the strength of the current, and, if there be several liquids in the same circuit, each having a different salt to be decomposed, the quantities decomposed in each, during the same time, are proportional to the atomic weights of the elements of which the salts are composed Thus if there be two cells, one containing solution of iodide of potassium, and the other solution of common salt (chloride of sodium), for every 127 parts of iodine set free, there will be 35 5 of chlorine, and, at the same time, 39 1 parts of potassium, and 23 parts of sodium These numbers are the atomic weights of the respective elements

Lastly, we mention the physiological effects of the electric current It was by means of these that current electricity was discovered by Galvani While using the lower limbs of a newly killed frog as a very delicate kind of electroscope, he was startled to find that the contact of a compound bar of copper and iron produced a violent convulsion or contraction of the muscles, when the copper and iron ends of the bar were made to touch two separate portions of the body at the same time (See *Galvanism*) There is nothing so delicate as the limbs of a frog for detecting this action, but with a few cells of a battery, a contraction of the muscles and shock is easily felt on opening and closing the circuit If a copper and zinc plate be put one above the tongue and the other below, and made to touch each other, a peculiar taste or sensation in the tongue is felt which is due to the passage of electricity This sensation is extremely delicate A battery quite unable to give a telegraphic signal, with an ordinary instrument, may readily be made to give the *electric taste* If plates of platinum, coming one from each end of a battery, are placed between the gums and the cheeks, on completing or on breaking the circuit, a flash of light is seen before the eyes, and if the wires coming from the ends of a battery of 30 cells are inserted in the ears, a peculiar continuous sound is heard (See *Electricity, Physiological Effects, Electricity, Animal, &c*)

The most important source of the electric current is chemical action As has been already mentioned, a current is produced when a plate of zinc and a plate of copper are immersed in dilute sulphuric acid, and connected outside the liquid by means of a wire or other conductor, and we have defined the direction of the current to be from the copper through the wire to the zinc There are many other forms of cell in which chemical action is made use of as the sustainer of the current, and these are described under *Battery, Galvanic*, and under their several names (See *Battery, Galvanic*)

Heat is another source of the electric current When two bars of different metals are joined together at the ends so as to form one compound circuit, then if one of the junctions be kept at a higher temperature than the other, a current will pass in the circuit in a direction depending upon the nature of the metals, but perfectly definite when the two metals are known (See *Thermo Electricity* and *Thermopile.*)

The last source of the electric current is *induction*, which, however, must be carefully distinguished from statical induction, as a source of electric excitement When a wire, through which a current is passing, is brought near to a second wire which is formed into a closed circuit by joining its ends together, a temporary current is produced in the latter, and, on again carrying it away, a temporary current is produced in the opposite direction, or if we place in the vicinity of a wire forming a closed circuit, another wire which can be suddenly connected with and disconnected from a battery, a current in one direction is induced in the closed wire each

time the connection is made with the battery, and a current in the opposite direction each tim it is broken Again, when a magnet is brought near to a closed wire or carried away from i a current is produced If, for example, a magnet be suddenly dropped into the middle of a co of wire, a temporary current circulates the coil, and if the magnet be suddenly withdrawn, current passes through the coil in the opposite direction The subject of induced currents treated of under *Induction, Electro dynamic* They are of great importance to us, for thoug they are, as we have mentioned, only temporary, they can be made use of by means of prope arrangements for producing them, and they possess the properties of having a high power fo overcoming resistance together with very considerable quantity (See *Induction, Electro dyna mic*, *Induction Coil*, *Current, Induced*)

CURRENT, EXTRA It is explained under *Current, Electric*, that a current suddenl generated or stopped in a wire connected with a battery induces a temporary current in anoth wire placed near to it But this action is even more extensive, for the current passing in wire acts inductively upon the wire which transmits it, and at the moment when it begins t pass, and at the moment when it ceases, produces currents, the first *inverse*, the second *dire* These are called *extra currents* The effect of the first, which is produced at the instant o making connection with the battery, is simply to retard the primary current and to prevent i instantaneous transmission through the wire, the second, occurring at the cessation of th primary current, lengthens out its existence, and that with increased power The properties o the extra currents are similar to those of ordinary induced currents, they possess considerab quantity combined with high power of overcoming resistance, and thus exhibit at the same tim calorific, chemical, and violent physiological effects To examine them it is necessary to avo the effect of primary current upon the instruments for measuring Edlund, who has investi gated the question, has given the following laws regarding them —

The extra currents obtained on opening and on closing the circuit have the same electromoti force

The electromotive force of the extra current is proportional to the strength of the primary curren

CURRENT, HEATING EFFECTS OF The laws of the production of heat by th electric current have been investigated by Joule in connection with his determination of th dynamical equivalent of heat The passage of an electric current gives rise to a certain amou of heat, which may be produced within the pile or cell itself, in the interpolar wire, or in bot The following are the laws according to which the heat is generated —

(1) The total quantity of heat produced in the cell and in the wire in a given time is pr portional to the electromotive force, and to the quantity of electricity which has passed in th circuit in that time, or, in other words, it depends on the construction of the cell, since t electromotive force depends on that, and on the amount of chemical action (excluding, of cours local action on the plates) which has gone on within it, since the quantity of electrici depends upon that

(2) This heat is distributed between the interior of the cell and the interpolar wire in simp proportion to the resistance in each

Another way of stating the same laws is that the heat generated in any part of the circu suppose in the interpolar wire, is proportional to the resistance of it and to the square of t strength of the current It appears from this that by increasing the strength of the curre or the resistance of the wire any temperature may be obtained, and, in fact, it is easy, by usi a fine wire so as to give great resistance, and a sufficiently powerful battery to produce a co siderable current through it, to obtain a heat so intense as to fuse the wire however refracto The heat of the current has been employed together with that of the sun's rays, to melt ve infusible minerals, and even the diamond and plumbago have yielded to its power

CURRENT, INDUCED As has been stated under *Current, Electric*, the production stoppage of a current in the vicinity of a wire formed into a closed circuit gives rise to a te porary current in it The current thus produced is called an *induced current*, and t phenomenon is spoken of as *current induction* Suppose that we have two wires, one of the formed into a closed circuit, including a galvanometer in it, and the other arranged in co nection with a battery and key so that a current may be sent through it and stopped pleasure, and let portions of the two wires be laid parallel and near to each other Then suddenly making connection with the battery and thus sending the current through the w joined to it the galvanometer will be affected, showing that a current has traversed the otl wire But the needle soon falls back to its place, the current being only momentary, now again breaking connection with the battery and thus stopping the current in the first wire temporary deflection of the galvanometer will again occur, and in the opposite direction to th which took place before, showing that a second transient current has been produced, and co trary in direction to the first. Also on comparing the direction of the *primary* current, as th

from the battery is called, with that of the *secondary* or *induced current* in the parts of the wire that are parallel, it is found that the direction of the induced current obtained on making connection with the battery is *opposite* to that of the primary current, that of the induced current obtained on breaking connection with the battery is the same as that of the primary current. The first is called the *inverse* current, the second the *direct* current.

A more powerful arrangement for exhibiting the effects of current induction is constructed by using wires insulated by covering with silk or cotton, and winding the primary and secondary wires side by side into a coil, or by winding them into two separate coils, and putting one inside the other. In that case every turn of the primary wire acts on every turn of the secondary wire, and the effect is much heightened.

Induction also takes place between two wires, one of which is transmitting a current when the distance between them is altered. Thus if the primary wire be brought nearer to the secondary wire, an inverse current takes place, if it be removed a direct current. Again, if a permanent magnet be brought near to or removed from, a coil connected, as described above, with a galvanometer, a direct and an inverse current are produced, the words direct and inverse being applied by looking on the magnet as a solenoid, whose currents pass according to the hypothesis of Ampère's theory (*q v*).

The laws of the effect produced upon a secondary wire by the change of position of the primary wire, or of a magnet, are summed up in what is commonly known (from the name of the propounder) as Lenz's law. *The current produced in the secondary coil by the approach or removal of the primary, or of a permanent magnet, is such with regard to direction as would oppose that motion, according to the laws of electro-dynamics.* (Vide *Electro-dynamics*.)

The following are the laws of current induction with reference to strength, tension, and electromotive force —

The *strength* of either induced current is proportional to that of the primary current, and to the product of the lengths of the primary and secondary wires. The quantities of electricity transmitted by the direct and inverse currents are the same.

The *electromotive force*, or power of overcoming resistance, is greater in the case of the direct current than in that of the inverse.

Upon the induction due to currents a great number of most useful and important instruments depend for their action, and these will be found described in their proper places. For example, induced currents have entirely taken the places of static discharges for medical purposes, they are being used more and more for illumination in light-houses and similar places, while for the performance of certain optical experiments they are indispensable. (See *Rhumkorff's Coil*.)

The inductive action does not stop here. The induced currents are themselves able, as Henry has shown, to produce new induced currents which are termed induced currents of the *second order*, and these again to produce induced currents of the *third order*. These may be shown by using a series of concentric bobbins, and their laws have been investigated by Henry and Abria. They are alternately in opposite directions. Thus, on closing the primary circuit, which is always considered direct, the induced current of the

First order is Inverse,
Second order is Direct,
Third order is Inverse,

and so on. On opening the primary circuit, the direction of the induced current of the

First order is Direct,
Second order is Inverse,

and so on. In each of the orders the *strength* of current, direct or inverse, is the same, and the electromotive force of the direct current much greater than that of the inverse, and in the currents of the successive orders, compared with each other, the electromotive force decreases as the number of the order increases.

CURRENT, STRENGTH OF. The strength of a current is proportional to the quantity of electricity conveyed by it in unit time. (See *Units, Electrical*.) According to the laws of electro chemical decomposition, the amount of decomposition is proportional to the strength of the current. It is upon this principle that Faraday's Voltameter is constructed. The current to be measured is applied to decompose water, and the amount of gas given off is collected and measured. The strength of the current is thus proportional to the amount of gas produced in a given time, and unit strength might be defined to be such that a current of unit strength would produce one cubic inch of gas per minute. We cannot, however, make use of this method to measure the current which a given cell or battery can produce, for the introduction into the circuit of such high resistance as that of a decomposing cell, very much decreases the current actually transmitted by the cell or battery. But by making use of a galvanometer in connection with the voltameter, this measurement may be accomplished. If the current be

passed through a tangent galvanometer (see *Galvanometer*), the strength of the current is proportional to the tangent of the angle through which the needle is deflected. By including, therefore, a voltameter and a tangent galvanometer in one circuit, and noticing the quantity of gas given off in a certain time, while the galvanometer indication is also noted, the relation of the former to the latter may be once for all determined, and the strength of any current thenceforward determined by a simple calculation from the deflection of the galvanometer.

CURRENT, PARTIAL. See *Derived Currents*.

CURRENT, PRINCIPAL. See *Derived Currents*.

CURRENT, THERMAL. See *Thermo-Current*, *Thermo-Electricity*.

CURRENTS OF THE SEA, THE EFFECT OF, ON CLIMATE. See *Climate*.

CURSA. (Arabic.) The star β of the constellation Eridanus.

CURVE OF SPACES. In kinematics the curve whose ordinates are proportional to the spaces passed over by a moving body in times proportional to the abscissæ. If points be taken on a straight line at distances proportional to the times of observation, and lines be drawn at these points perpendicular to the first line, and proportional to the spaces described by the body from some fixed point, the curve joining the extremities of these lines is the curve of spaces. The chief properties of the curve of spaces are as follows:—

The points in which the curve cuts the axis of time represents intervals in which the particle returns to its initial position. A point of inflection marks a sudden change of direction. The velocity at any point will be found by drawing a tangent to the curve at that point, and then drawing two ordinates to meet it, whose distance represents one unit of time; the difference of these ordinates is the velocity. Points at which the tangents are parallel to the axis of time mark instants during which the velocity is zero, or, in other words, the particle stands still in its path for an indefinitely small interval of time.

CURVE OF VELOCITIES. In kinematics, a curve whose ordinates are proportional to the velocities of a moving particle, and whose abscissæ are proportional to the intervals of time at which the velocities are taken. If points be taken on a straight line at distances proportional to the intervals between the times of observation, and lines be drawn at these points perpendicular to the first line or axis of time, and proportional to the velocities of the particle at the instants represented by the points, then the curve joining the extremities of those lines is the curve of velocities. This name was given to the curve by Newton. Its chief properties are as follows:—

The negative values of the velocity are represented by negative ordinates, and therefore these represent retrograde motion. The area of the curve of velocities represents the whole space passed over by the particle in the time represented by the portion of the axis between the extreme ordinates. At points indicated by a change of inflection, the velocity has a maximum or minimum value.

CURVES, MAGNETIC. The lines into which iron filings arrange themselves, under the influence of a magnet, are called the *magnetic curves*. To produce them a sheet of white paper, stretched on a frame, is placed over the magnet or magnets or any masses of magnetic matter laid on a horizontal table. Fine iron filings are then lightly scattered over the paper, and with the aid of gentle tapping, can be made to distribute themselves in lines, the form of which depends upon the nature and shape of the magnet or magnets made use of. These lines are the magnetic curves. In the case of an evenly magnetised straight bar, they start from one pole and curve round in the shape of an oval, to meet the centres of the magnets at points near the other pole, corresponding to those from which they take their rise. By arranging masses of magnetic matter in the magnetic field, or by bringing near to each other like and unlike poles of various sizes and strength, very curious and beautiful forms of curves are obtained, which it is quite impossible to describe. The lines thus traced out have a very great interest, since they are the *lines of magnetic force* due to the particular arrangement of magnetic matter used. The reader may also consult *Lines of Force* and *Field of Force* for some further information on this subject.

CYANOGEN. (κυανος, blue; and γενναω, to produce.) A gaseous compound of carbon and nitrogen of the formula C_2N_2. It is a colourless, very heavy gas of a peculiar suffocating odour; density, 1·806. At a pressure of about four atmospheres, or at a temperature of about $-4o°C$ ($-4o°F$) at the ordinary pressure, it liquifies, and at a little lower temperature it freezes to a crystalline mass. Gaseous cyanogen is very inflammable, burning with a peach-blossom coloured flame, producing carbonic acid and nitrogen. It dissolves slightly in water, alcohol, and ether, and is absorbed by alkaline solutions. In its chemical characters cyanogen closely resembles an element of the chlorine group, and on this account it is generally designated by the symbol Cy. It unites directly with metals, forming cyanides, which are analogous to chlorides, &c.; it also forms a hydrogen compound, *Hydrocyanic Acid* (which see), and an oxygen compound, *Cyanic Acid* (CNHO). The following compounds of cyanogen may also be mentioned:—

Cyanide of Potassium (KCN or KCy) In the pure state this forms transparent cubical crystals which deliquesce and decompose on exposure to air, exhaling the odour of prussic acid at a dull red heat, it melts to a transparent liquid, solidifying to an opaque porcelain-like mass Commercial cyanide of potassium is a mixture of cyanide and cyanate of potassium Cyanide of potassium is a powerful reducing agent, especially at a red heat, and is largely used in analytical chemistry, and in manufactures The solution possesses the valuable property of dissolving many insoluble salts of silver and gold, and retaining the metal in a form in which it is easily precipitated in the metallic state by galvanic action It is therefore of great use for electro-plating and gilding Cyanide of potassium, added to solutions of heavy metals, precipitate insoluble cyanides of these metals When more cyanide of potassium is added, the insoluble cyanide is dissolved, and in some cases (for instance, with iron, cobalt, &c) a new salt is formed, containing a compound metallo-cyanogen radical, united with potassium, thus, in the case of iron, *ferrocyanide of potassium* is formed and with cobalt, *cobalticyanide of potassium* In other cases, however, no such double salt is formed, thus with nickel, there is simply obtained a solution of cyanide of nickel in cyanide of potassium Some ferrocyanogen compounds are of importance (See *Ferrocyanide of Potassium, Prussian Blue*)

CYANOMETER (κυάνός, a blue substance, and μέτρον, measure) An instrument devised by Saussure for measuring the depth of the sky's blue tint It consists simply of a circular card, radially divided into fifty-one parts, each of which is coloured to a different tint of blue The card is held between the observer and the sky, and the tint on the card which corresponds most closely with the colour of the sky is noted and recorded by its number

CYCLE (κύκλος, a circle) The period within which a series of celestial phenomena recurs. It has been justly remarked that no celestial phenomenon ever recurs identically, and far less will any series of phenomena be repeated a second time precisely as at its first occurrence Nevertheless certain marked phenomena are repeated to all intents and purposes in a cyclic manner, and the object with which the so called cycles of chronology and astronomy have been formed has been to bring the recurrence of different sets of phenomena into association one with another, by selecting time-intervals which include a definite number of recurrences of each set, without any important fractional remainder The following are the principal chronological and astronomical cycles

The Solar Cycle This is a period of twenty-eight years Within each such period the first day of the year passes successively through the same sequence of week days If every year consisted of 365 days, the successive new-year days would be the successive days of the week But after a leap year one day is missed Supposing a series of years to begin with the days Monday, Tuesday, Wednesday, and Friday (Thursday being the day missed), the next set of four years would end with the omission of Monday, the next with the omission of Friday, the next with the omission of Tuesday, and so to Saturday, Wednesday, Sunday, and then to Thursday again In other words there would be seven sets, of four years each, before the series would be completed, or twenty eight years in all With the Julian calendar there was no change in the solar cycles (See *Bissextile, Calendar*) But with the Gregorian Calendar there is always a break in passing from one century to another, except when the new century belongs to the series 1600, 2000, 2400, &c

Cycle of Indiction A period having reference to an edict issued by the Roman emperors every 15 years It is therefore quite arbitrary, but as it is often referred to in old chronicles it is necessary to state the rule for determining the position of every year in the cycle of indiction This rule runs thus —Add 3 to the number of the year and divide by 15, the remainder is the number of the year in the cycle of indiction Thus for the year 1870, we have $\frac{1870+3}{15} = 124 + \frac{13}{15}$, therefore 1870 is the thirteenth year of a cycle of indiction The cycle is supposed to date from the year 312, so that we may determine both the year of the cycle, and the number of past cycles, by subtracting 312 from the number of the year and dividing by 15 as before Thus we have $\frac{1870-312}{15} = \frac{1558}{15} = 103 + \frac{13}{15}$ Therefore, 103 cycles of indiction have passed, and the year 1870 is the 13th of the 104th cycle.

The Metonic Cycle This is a cycle intended to associate the lunation with the year It was in reality invented by the Chinese (or was at least in use among them) long before Meton's time (about 432 B C) The period of a lunation is not contained an exact number of times in a year, but in 19 years there are almost exactly 235 lunations The actual difference is but 06 of a day, if the Julian year of 365¼ days be considered, since 235 lunations contain 6939 69 days, while 19 Julian years contain 6936 75 days Now, 06 of a day in 19 years corresponds to 1 day in about 317 years Thus, after 19 years the lunations would repeat themselves (always, however, with reference to the year of 365¼ days, and, therefore, with a possible error of 1 day in date) for about 317 years The Gregorian calendar introduces other discrepancies But the Metonic cycle is still dealt with in our almanacs, the "*golden number*" (used in finding Easter) being

calculated with reference to it The Metonic cycle has a relation also to *lunar eclipses*, which depend on the *nodical month* For 235 lunations are equal in length to 255 021 nodical months, so that at the commencement of each Metonic cycle the moon is not only in the same position with reference to the sun, but also nearly in the same position with reference to the nodes of her orbit The interval 021 of a nodical month, is however, too important for the Metonic cycle to be of much use as a cycle of eclipses

The Calippic Cycle This cycle was invented by Calippus, who flourished about a century after Meton He endeavoured so to improve the Metonic cycle as to obtain a readier means of representing the recurrence of eclipses To effect this he deducted one day from four Metonic cycles, thus obtaining a period of very nearly 940 lunations, 1020 nodical months, and 1016 sidereal months The Calippic cycle was not exact enough to be of much more use than the Metonic, so far as eclipses were concerned, and was for other purposes altogether inferior to the cycle

The Saros or Chaldean Cycle This cycle was a singularly successful attempt to master the difficulty of predicting the recurrence of eclipses It consisted of 223 lunations It thus fell short of 242 nodical months by about 39 minutes, and of 239 anomalistic months by rather less than 5 hours It exceeded 241 sidereal months by less than a day Thus in each successive saros eclipses very nearly recur, take place nearly in the same part of the celestial sphere, nearly correspond in character (as regards at least the apparent dimensions of the moon) The cycle not having any reference to the year, the dates of eclipses are not at once indicated by it The Chaldeans calculated the length of the saros at $6585\frac{1}{3}$ days, so that the eclipses would not recur at the same hour of the day But by trebling the period this difficulty was got over Their estimate was very accurate, the total error in the triple saros being somewhat short of one hour, or more exactly 58m 6s

The Paschal Cycle is an ecclesiastical one, and need not here be considered

CYCLONES (κύκλος) Rotatory storms, which take their rise in tropical seas, and commonly travel along a parabolic path, which carries them first towards the west and afterwards towards the east (with a northward motion throughout) Thus the Atlantic cyclones, when as sometimes happens they reach our shores, come always from the west In the Chinese seas these storms are called *Typhoons* The diameter of the cyclonic whirlwind varies from about 170 to about 500 miles or more The centre, where calm prevails, travels at a rate varying from 2 to about 30 miles per hour The direction of rotation is different for the two hemispheres In the northern hemisphere the direction is contrary to the motion of the hands of a watch (placed face upwards on the map), in the southern the reverse is the case Captain Maury considers that cyclones travel over the course of warm sea-currents, and that even when generated at some distance from such currents they make their way to the channel of warm and rarified air existing above those ocean streams Such storms are also called *Tornadoes* (See *Winds*)

CYGNUS (The Swan) One of Ptolemy's northern constellations This asterism is principally remarkable as including one of the richest portions of the Milky Way visible in our latitudes Within its range also is a somewhat well defined vacuity which has been termed the northern Coalsack The star Albireo on the beak of the Swan is a fine double, the colours of the components being orange and blue, and very well marked But the most interesting object in this fine constellation is undoubtedly the binary star 61 Cygni By two distinct methods the distance of this pair has been found to be about three times as great as that of the star Alpha Centauri From the observed motions of the system it has been concluded that the two stars together weigh about one-third as much as our own sun

CYLINDRICAL LENS A lens, whose curvature is that of a cylinder, instead of a sphere A cylindrical glass rod may, therefore, be called a cylindrical lens Lenses of this kind are generally cylindrical on one side only, and flat on the other They bring the image of a source of light to a line instead of a point, and are frequently used in optical instruments and stellar spectroscopes

DAGUERREOTYPE PROCESS The original process of photography, so named after its inventor M Daguerre A highly polished plate of silver is exposed in darkness to the vapour of iodine, or a mixture of iodine and bromine, until its surface is of a reddish yellow colour, it is then exposed for a short time to the luminous image in a photographic camera, and transferred to the dark operating room Here the impressed plate (on which, however, no image is visible) is exposed to the vapour of mercury The metal will adhere in the form of a light gray powder to those parts of the surface upon which the light has shone, but will not touch the

portions unacted on When sufficiently developed the unaltered iodide or bromo iodide of silver is dissolved off with hypo-sulphite of soda, when the picture is fixed This process is now almost obsolete (See *Photography*)

D'ALEMBERT'S PRINCIPLE Suppose a number of forces to act upon a rigid body, and suppose it be required to determine the motion of any particle of the body Two sets of forces will act upon that particle, first, the forces impressed from without, secondly, the cohesive pressures which bind it to the rest of the body The force producing motion will be the resultant of these two sets of pressures Let us call this resultant the effective force If to each point of the body a force be applied equal and opposite to the effective force at the point, the whole will be in equilibrium It is impossible, however, to determine the forces of the second group D'Alembert made the following assumption —"The internal action and reaction of any rigid system in motion are in equilibrium amongst themselves" From this the law known as D'Alembert's principle immediately follows, viz, "If pressures equal and opposite to the effective pressures at any instant were at that instant applied to each point of the body, they would be in equilibrium with the impressed pressures"

DALTONISM See *Colour Blindness*

DALTON'S LAW See *Evaporation*

DANIELL'S GALVANIC BATTERY In this arrangement the cells are formed in the following manner —A copper plate is immersed in a saturated solution of sulphate of copper This plate is generally rolled up so as to form a vertical cylinder, and within it is placed a porous cell of bladder, or of unglazed earthenware The porous cell is filled with dilute sulphuric acid, and a plate or rod of zinc is placed within it According to the common phraseology, the current proceeds from the zinc through the liquid to the copper when the circuit is closed

The advantage of the Daniell's battery is its great constancy, and it is found in this respect far to supersede any other arrangement at present in use

The following is an account of the chemical action that takes place within it —At the zinc surface the sulphuric acid is decomposed, sulphate of zinc is formed, and hydrogen is liberated This gives rise to an action at the surface of the porous cell, by which the hydrogen, thus set free is furnished with sulphur and oxygen, and reconverted into sulphuric acid at the expense of the sulphate of copper in the exterior cell A third reaction takes place at the surface of the copper plate, by which copper, liberated in consequence of the last reaction, is deposited on its surface This will be readily understood from the following representation, in which the ordinary chemical symbols are used, the vertical line in the middle representing the porous diaphragm The first line shows the condition before the chemical action begins, the second, the condition after one series of changes has occurred —

$$\text{Copper plate, Cu, } \overset{\frown}{CuSO_4},\ \overset{\frown}{CuSO_4}\ |\ \overset{\frown}{H_2SO_4},\ \overset{\frown}{H_2SO_4},\ \text{Zn, Zinc plate}$$

$$\text{Copper plate, } \overset{\frown}{Cu\,Cu},\ \overset{\frown}{SO_4Cu},\ \overset{\frown}{SO_4}\ |\ H_2,\ \overset{\frown}{SO_4H_2},\ \overset{\frown}{SO_4Zn},\ \text{Zinc plate}$$

The sulphuric acid diffuses towards the zinc plate through the porous diaphragm It appears thus that the polarisation of the copper plate due to the deposition of hydrogen is completely avoided The sulphate of copper is used up, but this is continuously supplied from a shelf within the outer cell which carries a heap of crystals The only limit to the constancy is the formation of sulphate of zinc in such quantity as to prevent the action of the zinc plate

DARK HEAT RAYS See *Obscure Heat, Calorescence*

DAWN See *Twilight*

DAY In its original acceptance this term meant the interval between sunrise and sunset We still use the term in this sense when we compare day with night Another familiar usage of the term refers to the completion by the sun of his apparent circuit of the heavens, as either from sunrise to sunrise, or from sunset to sunset, or, more exactly than either, from southing to southing The former has been called the *artificial*, the latter the *natural* day, though it would be difficult to assign a reason for the use of the first of these titles to describe a purely natural phenomenon

We are concerned here, however, with those uses of the term day which are founded on astronomical relations These are the following —

The *apparent or true solar day* —This is the interval which elapses between the successive returns of the sun to the meridian If the earth travelled at a uniform rate round the sun, and her axis were at right angles to the plane of her orbit, so that the ecliptic and the equator coincided, the solar day would be of constant length But neither of these relations holds, and thus the solar day is variable, though the limits of variation are not very wide The true solar day is not used even among astronomers as a measure of time, for which indeed it would be wholly unsuitable

The *civil or mean solar day* —This is the interval which would elapse between successive

returns of the sun to the meridian if the relations referred to in the preceding paragraph really held It may be described as the mean length of the true solar day If a sun were supposed to travel uniformly along the celestial equator, so as to accomplish one complete revolution in a year, the successive returns of that sun to the meridian would be separated by a mean solar day The civil day is divided into 24 hours, which are counted in two sets of 12 Astronomers, when they use mean solar time either for reference or in practice, count through 24 hours, beginning from noon Thus, in astronomical parlance, 5h January 27, means 5h P M January 27, but 15h January 27 corresponds to 3h A M January 28, according to civil reckoning

The *astronomical or sidereal day* —This is the interval which elapses between a star's successive passages of the meridian of a place, and therefore corresponds to the period of the earth's rotation on her axis This interval is appreciably constant It has been suspected indeed (see *Acceleration of the Moon's Mean Motion*), that the period of the earth's rotation is very slowly increasing, and it might be urged that, since no star is absolutely fixed, the successive returns of a fixed star to the meridian are not separated by an interval which is *exactly* equivalent to the period of the earth's rotation But neither correction would be appreciable, even in the most exact astronomical processes, carried on for many successive years, so that neither affects the claim of the sidereal day to be regarded as the most convenient unit of time-measurement which the astronomer can select The length of the sidereal day has been calculated with a degree of niceness proportioned to that of the determination of the sidereal year In fact, the two periods are closely interdependent, for we have this rule—the number of sidereal days in a sidereal year exceeds by one the number of mean solar days Now the determination of the number of solar days in a sidereal year is a problem towards the solution of which the whole duration of astronomical observation is available Whatever error there may be in the comparison between the first available observation and one made yesterday (if we will) at Greenwich, is distributed among the whole number of years separating the two observations, and therefore affects in an indefinitely minute manner the determination of the length of a single year Hence we can rely with extreme confidence on the value assigned to the sidereal year—that is, 365 2563612 days And with corresponding confidence we can accept the value of the sidereal day as

$$\frac{365\ 2563612}{366\ 2563612} \text{ of } 24\text{h},$$

which reduces to 23h 56m 4 092s

Astronomical clocks are set to keep sidereal time, each sidereal day reckoning from the transit of the first point of Aries

DAYLIGHT, ACTINIC INTENSITY OF Dr Roscoe has given a method for the meteorological registration of the actinic intensity of total daylight, (*Phil Trans*, 1865, p 605), founded upon an exact measurement of the tint which standard sensitive paper assumes when exposed for a given time to the action of daylight Measurements of the actinic intensity, according to this plan, have been made for some years at Kew, and, in 1866, Dr Roscoe's assistant Mr Thorpe, was enabled to take a series of observations in the same manner at Pará, under the equator, in a situation possessing a clear horizon By comparing the daily mean intensities at Pará and Kew, on the same days, we gain some idea of the true chemical action of the tropics, and it becomes evident that the alleged failure of photographers working in tropical countries cannot, at any rate, be ascribed to a diminution of the sun's chemical intensity The following table exhibits the daily mean actinic intensities at Kew and Pará for fifteen days, in April 1866 (*Phil Trans*, 1867, p 564)

DAILY MEAN INTENSITY

Date		Kew	Pará	Ratio.
1866.	April 4		269 4	
	" 6	28 6	242 0	8 46
	" 7	7 7	301 0	39 09
	" 9	5 9	326 4	55 25
	" 11	25 4	233 2	9 18
	" 12	55 8	203 1	3 66
	" 13	52 2	337 8	6 46
	" 14	38 5	265 5	6 89
	" 18	39 8	350 1	8 80
	" 19	75 2	352 3	4 68
	" 20	38 9	385 0	9 90
	" 23	80 4	350 1	4 35
	" 24	83 6	362 7	4 34
	" 25	73 7	307 8	4 17
	" 26	39 1	261 1	6 67
Mean intensity,		46 06	303 2	

Hence it appears that the actinic action of total daylight, in the month of April 1866, was 6 58 times as great at Pará as at Kew (See *Actinometer*, *Chemical Action of Light*, *Photochemical Induction*)

In a communication to the Royal Society, in April last, Drs Roscoe and Thorpe give the results of a series of observations of the actinic intensity of total daylight, made on the flat table land on the southern side of the Tagus, near Lisbon, under a cloudless sky, with the object of ascertaining the relation exising between the solar altitude and the chemical intensity The chemical action of the total daylight was first observed in the ordinary manner, the chemical intensity of the diffused daylight was then observed by throwing on to the exposed paper the shadow of a small blackened brass ball, placed at such a distance that its apparent diameter seen from the position of the paper was slightly larger than the sun's disc The sun's altitude was determined by a sextant and artificial horizon 134 sets of observations were made, and they were divided into seven groups, according to the number of hours they were from noon It had before been proved that the mean actinic intensity of total daylight for hours equidistant from noon is constant, and the result of the Lisbon series of experiments proves that this conclusion holds good generally In the paper curves are given, showing the daily march of chemical intensity at Lisbon in August, compared with that of Kew for the preceding, and at Pará for the preceding April The value of the mean chemical intensity at Kew is represented by the number 94 5, that at Lisbon by 110, and that at Pará by 313 3, light of the intensity 1 0, acting for 24 hours, being taken as 1000 The following table gives the results of the observations arranged according to the sun's altitude —

Number of Observation	Mean Altitude	Chemical Intensity Sun	Chemical Intensity Sky	Total
15	9°51′	0 000	0 038	0 038
18	19 41	0 023	0 063	0 086
22	31 14	0 052	0 100	0 152
22	42 13	0 100	0 115	0 215
19	53 09	0 136	0 126	0 262
24	61 08	0 195	0 132	0 327
11	64 14	0 221	0 138	0 359

At altitudes below 10° the direct sunlight is robbed of almost all its actinic rays The relation between the total chemical intensity and the solar altitude may be represented graphically by a straight line for altitudes above 10° A similar relation has already been shown to exist for Kew, Heidelberg, and Pará, so that although the actinic intensity for the same altitude at different places and at different times of the year, varies according to the varying transparency of the atmosphere, yet the relation at the same place, between altitude and intensity, is always represented by a straight line, this variation, in the direction of the straight line, is due to the *opalescence of the atmosphere* (which see), and it is shown that for equal altitudes the higher intensity is always found where the mean temperature of the air is greater, as in summer, when observations at the same places at different seasons are compared, or as the equator is approached when the actions at different places are examined The differences in the observed actions for equal altitudes, which may amount to more than 100 per cent at different places, and to nearly as much at the same place at different times of the year, serve as exact measurements of the transparency of the atmosphere

DECANTATION (*Decanter*, to pour off) The act of pouring a liquid from one vessel into another In chemistry it is generally practised for the purpose of separating a clear liquid from a precipitate which has settled to the bottom of the vessel Washing by decantation is performed by stirring up the sediment with pure water, allowing it to settle, and then pouring off the clear liquid, and repeating the operation until all the soluble salts are extracted

DECLINATION (*Declino*, to deviate from.) The angular distance of a celestial body from the equator, measured along a great circle passing through the body and the pole of the equator

DECLINATION CIRCLE See *Circle of the Celestial Sphere*

DECLINATION COMPASS See *Declinometer*

DECLINATION, MAGNETIC A magnetised needle free to move in a horizontal plane, takes up a definite position which depends upon its place on the earth's surface At certain places it points due north and south, but in general it makes a small angle with the geographical north and south line, and the line in which it points is frequently called the line of *magnetic* north and south A vertical plane passing through the points where this line cuts the horizon, is called the plane of the *magnetic meridian*, just as the vertical plane, taking in the true north and south points, is called the plane of the geographical meridian, and the angle between these

two planes is called the *magnetic declination* In England this angle amounts to nearly 20° at present (See also *Magnetism, Terrestrial*)

DECLINATION NEEDLE Another name for the Declinometer, (*q v.*)

DECLINATION PARALLEL See *Parallel*

DECLINOMETER. (*Declino*, to deviate from, and *μετρέω*, to measure) Is an instrument for measuring the magnetic *declination* or the angle which the plane of the magnetic meridian makes with the plane of the geographical meridian There are several forms of declinometer We shall describe one of the most useful here Under the head *Magnetometer, Gauss's*, and *Balance, Bifilar*, will be found a description of the instrument used in observatories, and under *Observatory, Magnetic*, some remarks on the self-recording instrument A declinometer, in order that it may be of use as a portable instrument, requires first a needle for showing the magnetic meridian, and secondly an arrangement for determining the geographical meridian and for comparing the two together It consists of an ordinary compass with the needle very delicately suspended, and having marked on the card a circle divided into degrees and quarters of a degree To the opposite sides of the compass box, at the points marked 90° and 270°, are attached two uprights which carry a telescope on a horizontal axis The telescope is arranged to determine the greatest altitude, and thus obtain the geographical meridian The whole compass box, with the telescope attached, and furnished with a vernier moves on a graduated circle which is supported on a tripod and is capable of being adjusted horizontally by means of levelling screws Suppose then, that either by taking the greatest altitude of the sun or by observing a star, whose position is known, the plane of the astronomical meridian is ascertained and the compass box placed so that the line of the telescope shall be in it If then the compass needle stands at zero of the circle in which it moves, the declination of the place is zero But if it does not, the angle to which it points east or west of the zero point can be read off and is the declination angle for that locality

DECOCTION (*Decoquo, decoctus*, *de*, from, *coquo*, to boil) The act of boiling a substance in water, or other liquid, for the purpose of extracting its soluble constituents The same term is also used for the solution which has been prepared in this manner Thus we speak of a decoction of logwood

DECOMPOSITION OF LIGHT White light consists of the various colours which constitute the spectrum, it may be decomposed into its component colours in many ways, by *refraction* through prisms, by *reflection* from coloured surfaces which absorb some rays and reflect others, or by transmission through coloured media which allow some rays to pass and stop others The colours of thin plates, of grooved surfaces, and those shown by polarised light and diffraction are produced by interference

DECREPITATION (*Decrepo*, *de*, from, and *crepo*, to crackle) A crackling noise made when certain salts, chloride of sodium for instance, are suddenly exposed to heat It is generally caused by the expansion and volatilisation of the water mechanically held within them, but it is sometimes due to the different expansion of the crystalline layers

DEFERENT (*Defero*, to carry from) A term belonging to the *Ptolemaic system*, (*q v*)

DEFLECTION (*Deflecto*, to turn aside) A ray of light or heat is said to be deflected when it is turned aside from its original path (See *Refraction*, *Reflection*, *Inflection*)

DEGREE OF LATITUDE The distance separating two stations on the earth, both on the same longitude-circle, at which the elevation of the pole of the heavens differs by exactly one degree

One of the earliest problems of exact astronomy was the determination of the length of a degree of latitude on the earth's surface, and, considering the instrumental means of the ancient astronomers, they solved this problem with surprising accuracy It may seem, indeed, to those unacquainted with the nature of the problem, that the estimates of Eratosthenes and Ptolemy (79⅙, and 59½ English miles, respectively), were but rough, while the estimate of Posidonius (68 95 English miles), may not unfairly be regarded as owing its accuracy rather to accident than to the exactness of his observations But in reality an error of 10 or 12 miles either way, in the solution of a problem of so much difficulty, must be regarded as very minute compared with what we might have expected under the actual circumstances of the case

Since the invention of the telescope, the problem has been attacked under more favourable conditions But we must regard rather as a happy guess than as a legitimate conclusion from the observations which had been made in his time, the suggestion made by Huyghens, that the degrees of latitude may vary in length on account of an oblateness of the earth's figure, resembling that observed in the figure of Jupiter Observations specially made to test this opinion (which was confirmed by the calculations of Newton), led to a rather perplexing result Cassini's observations caused him to conclude that the degrees of latitude grow shorter as the pole

is approached, and he thought, at first, that this result corresponded with the theory that the earth is flattened at the poles. When it was pointed out that the direct reverse is the case, he still asserted the accuracy of his observations, and thus for a time the figure of the earth was regarded by French astronomers as that of a prolate instead of an oblate spheroid. However, expeditions subsequently sent out to Lapland and to the equator, to set the question at rest, resulted in the discovery that the degrees of latitude grow perceptibly longer towards the poles of the earth. It is readily seen that this result proves the oblateness of the earth. For, if we consider an ellipse, we see that the curvature is least at the ends of the minor axis; in other words, the curvature corresponds to that of a larger circle at these points than elsewhere. From the ends of the major axis to those of the minor axis, the curvature corresponds to that of a continually increasing circle, so that the degree divisions also continually increase. The figure of the earth, then, is shown by these measurements to be that of a flattened or oblate spheroid. Later measurements have placed this result beyond all question. The following table, from Sir John Herschel's Outlines of Astronomy, indicates the mean length of a degree of latitude as estimated from observations made at various stations, and by different observers:—

Country	Latitude of Middle of Arc	Arc measured	Mean length of a degree at the middle latitude, in feet
Sweden,	66°20′ 10.0″ N	1°37′ 19.6″	365,744
Sweden,	66 19 37	0 57 30.4	367,086
Russia,	58 17 37	3 35 5.2	365,368
Russia,	56 3 55.5	8 2 28.9	365,291
Prussia,	54 58 26.0	1 30 29.0	365,420
Denmark,	54 8 13.7	1 31 53.3	365,087
Hanover,	52 32 16.6	2 0 57.4	365,300
England,	52 35 45	3 57 13.1	364,971
England,	52 2 19.4	2 50 23.5	364,951
France,	46 52 2	8 20 0.3	364,872
France,	44 51 2.5	12 22 12.7	364,572
Rome,	42 59	2 9 47	364,262
America,	39 12	1 28 45.0	363,786
India,	16 8 21.5	15 57 40.7	363,044
India,	12 32 20.8	1 34 56.4	363,056
Peru,	1 31 0.4 S	3 7 3.5	362,790
Cape of Good Hope,	33 18 30	1 13 17.5	364,713
Cape of Good Hope,	35 43 20.0	3 34 34.7	364,060

Of these measurements, taking them in order, the two Swedish are due to Svanberg and Maupertuis; the two Russian to Struve, and to Struve and Tenner; the Prussian measurement was made by Bessel and Bayer; the Danish by Schumacher; the Hanoverian by Gauss; the two English measurements were made by Roy and Kater; the two French by Lacaille and Cassini, and by Delambre and Méchain; Boscovich made the Roman measurement; Mason and Dixon the American; Lambton, and Lambton and Everest the two Indian; Lacondamine and Bouguer the Peruvian; while the two measurements at the Cape of Good Hope were made, respectively, by Lacaille and Maclear.

It will be evident, from this table, that the increase towards the pole, which proves oblateness, really does take place, though here and there discrepancies exist, due chiefly, no doubt, to errors of observation, but partly also to real irregularities in the figures of the earth's meridians. These irregularities are, however, by no means sufficient to interfere with the general run of the evidence.

More recently, a series of very careful measurements has been made in India under the superintendence of Sir George Everest. From these measurements, the length of a meridional degree was found to be, for latitude 26° 49′, 363,606 feet; and for latitude 21° 5′, 363,187 feet. These results accord well with those in the preceding table, and justify the following table which exhibits the estimated length of a degree of latitude in feet for every tenth degree:—

Latitude	Length of degree in English feet	Latitude	Length of degree in English feet
0°	362,734	50°	364,862
10	362,843	60	365,454
20	363,158	70	365,937
30	363,641	80	366,252
40	364,233	90	366,361

See also *Earth*.

DEGREE OF LONGITUDE A degree of longitude on the earth is a degree of arc on the circumference of any latitude-parallel It will be seen by a reference to *latitude* and *longitude*, that the estimation of a degree of longitude is a problem of much greater difficulty than the estimation of a degree of latitude For in measuring a degree of latitude the observers can always determine the latitude of either end or of any part of the arc they are engaged upon, with great ease and with the utmost certainty, whereas the exact determination of the real longitude of any part of an arc of a latitude parallel is a problem of great difficulty The geometrical processes are, of course, the same in both instances, the measurement of an arc of longitude is as effective towards the determination of the earth's figure (supposed symmetrical about its polar axis,) as the measurement of an arc of latitude, while, supposing the irregularities of the earth's figure to be appreciable, it is absolutely necessary that measurement should be made both in longitude and in latitude It is therefore satisfactory that attention has been bestowed upon the important problem of measuring extensive arcs in longitude, especially as telegraphic communication has now become so complete as to have in great part removed the difficulty depending on the determination of the longitudes of stations along any arc which is to be measured The chief astronomers of Europe are at present engaged in completing a trigonometrical survey by which an arc of longitude extending from Orsk in Siberia to Valentia in Ireland is to be measured The following table shows the effect of the compression of the earth's figure according to the value at present accepted, and it will be easy to infer the nature of the quantities to be determined in order that the actual departure from the spherical shape may be deduced from the measurement of arcs of longitude —

Latitude	Length of degree, in geographical miles, supposing earth spherical.	Length of degree in geographical miles, with the accepted value of the earth s compression	Excess due to ellipticity
0°	60 000	60 000	0 000
10	59 088	59 094	0 006
20	56 382	56 403	0 021
30	51 962	52 004	0 042
40	45 963	46 021	0 058
50	38 567	38 642	0 075
60	30 000	30 074	0 074
70	20 521	20 581	0 060
80	10 419	10 452	0 033
90	0 000	0 000	0 000

To reduce these results into English feet, it is necessary to remember that a geographical mile contains 60,456 English feet Thus, since the above table gives as the excess due to ellipticity 0 075 for one degree in latitude 50°, we find that a degree of longitude in latitude 50° should be greater than on a spherical globe of diameter as great as the earth's equator by 453 English feet Such a difference would of course be readily determined, but it is by a minute fraction of this difference that any error in the accepted estimate of the earth's compression is to be determined

DEGREE OF TEMPERATURE See *Thermometer*

DEGREES OF INCANDESCENCE See *Pyrometer*

DELIQUESCENCE (*Deliquesco*, to melt away, *de*, from; *liquesco*, to become fluid) The property which some compounds, such as chloride of calcium and phosphoric acid, possess of rapidly absorbing moisture from the atmosphere, and dissolving therein

DELPHINUS (The *Dolphin*) One of Ptolemy's Northern constellations It consists of a well marked cluster of small stars, bounded towards the north by a space singularly clear of lucid stars In the Palermo catalogue the two stars α and β are called Svalocin and Rotanev respectively These names appear to be merely the inversion of the name Nicolaus Venator

DENEB ADIGE (Arabic) The star α of the constellation Cygnus It is also called *Arided*

DENEB ALEET (Arabic) The star β of the constellation Leo It is also called *Denebola*, and sometimes simply *Deneb*

DENEB ALGIEDI (Arabic) The star δ of the constellation Capricornus

DENEBOLA (Arabic) See *Deneb Aleet*

DENSITY (*Densus*, thick) This term is used in physics to denote the ratio of the quantity of matter in a body to that in an equal bulk of some standard substance The

standard for liquids and solids is water at a temperature of 4° C (39 2° F), that is to say, at the temperature at which a given weight of water occupies the least bulk For gases hydrogen is usually taken as the standard The quantity of matter in a body is termed its mass Hence the densities of two bodies are directly proportional to their masses, and inversely proportional to their volumes At the same spot on the earth's surface mass varies exactly as the weight, hence at the same place the density and the specific gravity of the body will be the same

DENSITY, ELECTRIC A term introduced by Coulomb in connection with his experiments on the distribution of electricity The electric density at any point of the surface of a conductor may be defined as the quantity of electricity per unit area at that point (See *Electrostatics*, *Electricity*)

DENSITY, INFLUENCE OF, ON SPECIFIC HEAT See *Specific Heat*

DENSITY IN TRANSPARENT MEDIA, DETECTING DIFFERENCES OF See *Waves in Air, Instrument for Rendering Visible*

DENSITY OF THE EARTH See *Earth*

DEOXIDATION The partial removal of oxygen from any substance, without, however, totally abstracting it, in the latter case *reduction* is the more usual expression

DEPOLARISATION The thin plate of a doubly refracting crystal, which causes the production of colour when placed between the polariser and analyser of a polariscope, is sometimes called a depolarising film or depolariser, and the action which it exerts on polarised light is called depolarisation The depolariser doubly refracts the plane polarised light which is incident upon it, resolving it into two rectangularly polarised systems of waves which traverse the plate with different velocities (See *Polariscope*) The term *de*polarisation is always employed, but it is not strictly accurate It would be better to call the phenomenon *di*polarisation, as the ray of polarised light is not, strictly speaking, *de*polarised, but duplicated (See *Polarised Light*)

DEPRESSION OF THE HORIZON See *Dip of the Horizon*

DERIVED CURRENTS A term relating to the dividing up of an electric current by giving it more than one course to follow Suppose a cell or other rheomotor to be transmitting a current through a wire, and suppose that at any two points in the wire the end of a second wire are joined on, at one of these two points the current splits up, part passing through each wire, and at the other it again unites, the total quantity of current passing is increased by the introduction of this extra wire since the external resistance is diminished The following terms are used in connection with this subject The original current which was passing before the introduction of the second wire is called the *primitive current*, the total current which passes after the introduction of the new route is called the *principal* current Between the two points just mentioned the principal current traverses two circuits, that part of it which goes through the old wire is called the *partial* current, and that part of it which passes in the new wire is called the *derived current* There may, of course, be any number of wires inserted into the circuit in this way, each of them will carry a portion of the current, and according to the following law, that the amount of the currents in the several courses are inversely proportional to the respective resistances of those courses

DESCENDING NODE See *Node*

DESILVERISATION PROCESS See *Lead*

DEVIATION, ANGLE OF LEAST See *Angle of Least Deviation*

DEVIATION OF THE COMPASS A term almost synonymous with *declination*, which see It means the angle made by a compass needle at any place with the true north and south line

DEVIATION OF THE LINE OF THE VERTICAL A plumb line does not in all places hang vertically downwards Near a mountain, for example, the weight is somewhat attracted towards the mountain, as is seen in such a case as Maskelyne's Schehallien experiment (See *Earth*) But it has also been found that the plumb-line assumes a non-vertical direction where there is no neighbouring elevation to account for the phenomenon In the neighbourhood of Moscow, for example, Russian astronomers have found this to be the case, and some similarly anomalous facts have been noticed during the survey of India Doubtless the deviation is due to the existence, either of subterranean masses of great density on the side towards which the plumb-line is deflected, or else of vast subterranean cavities on the contrary side Whatever be the real explanation, it is obvious that the observed fact is one of extreme importance, and that in all geodetical processes the possibility of error arising from such deviations should be carefully considered

DEW A deposition of moisture from the air, caused by cold

It was observed in very early times that dew is only deposited on clear nights, and that such nights are commonly cold Hence it was concluded that the moon, planets, and stars, pour

down cold upon the earth, and that this cold generates dew. Aristotle was the first to suggest a more tangible explanation of the phenomena of dew. He observed that dew is generally (or, as he supposed, *always*) formed in serene weather, and that it is not formed on mountain heights. He argued that the disturbance of the air interferes with the formation of dew. Now he regarded the vapour of water as a mixture of heat and water, and he reasoned that such vapour cannot extend to any great height, because the heat would get detached from it; nor can it form in windy weather for a like reason. Hence he concluded that dew is produced by the fall of water, abandoned by the heat which had raised it; and he was able to put forward a very obvious reason, founded on his views respecting vapour, for the fact that dew is not seen in high places, or in windy weather. He derided the notion that the stars, planets, and moon, cause dew to be precipitated, arguing that the sun is the true cause, "since his heat raises the vapour from which the dew is formed so soon as that heat is no longer present to sustain the vapour." In the middle ages philosophers preferred the view which attributed the formation of dew to the stars. Baptista Porta, however, adduced evidence showing that this view is erroneous; for he found that dew is sometimes deposited on the inside of glass windows, and that a bell glass placed over a plant in cold weather is more copiously covered with dew within than without. He noticed also that some metals are more copiously moistened with dew on their under than on their upper surface. But though Porta had thus shown skill as an observer, he was yet unfortunate in rejecting that part of Aristotle's theory which was alone correct. Instead of viewing dew as arising from the condensation of vapour, Porta thought that the air itself was condensed.

The progress of observation next brought to light facts which have a most important bearing on the subject of dew. Muschenbroek, in making experiments on the quantity of dew forming at different heights from the ground, discovered that dew forms much more freely on some substances than on others. This showed with tolerable clearness that the precipitation of dew is not a regular process, (either of precipitation or deposition), going on merely according to the state of the atmosphere; for, under such a process all objects would be moistened alike. It seemed clear that in some way the dew must be drawn from the air by the object itself which it moistens. Thus attention was again attracted to Aristotle's theory that dew is caused by the condensation of vapour. But it was recognised that Aristotle's explanation requires to be modified, and instead of supposing the condensation of vapour to result in such a way as Aristotle supposed, it was held that there is simply a discharge of vapour from the air, caused by the cold of the object on which dew is seen to form. Experiments were applied to test this view, and all doubt was removed by their success. It was found that, whenever a cold body is introduced into an atmosphere which contains much aqueous vapour, a portion of the latter invariably condenses and forms a dew upon the cold body. The familiar experiment of breathing upon a window is perhaps the simplest illustration of the phenomenon in question.

The principle thus established is most important. It is simply this. To air at a given temperature a certain proportion of aqueous vapour may be added without condensation resulting; but if in any way the temperature of the air be sufficiently lowered, there will presently follow a condensation of a portion of the aqueous vapour.

It should be added that this fact had been clearly enunciated before Dr Wells began the researches now to be described; so that it is a mistake to include it among the results of those researches, though the evidence supplied on the point by Dr Wells's experiments is most interesting and convincing.

We owe to Dr Wells the most complete and thorough investigation yet made on the subject of dew. His observations were made during the years 1814–17, in a garden in Surrey, three miles only from Blackfriars Bridge. He exposed little bundles of wool, carefully weighed when dry, and estimated the deposition of dew by their increase of weight as the dew moistened them. First comparing the amounts received on different nights, he found that though cloudy weather and windy weather were alike unfavourable to the formation of dew, yet that dew was at times formed on a cloudy night, and at times on a windy night; though never on a night that was both cloudy and windy. He found, further, that the quantity of dew deposited was less or greater, according as the proportion of clouded sky was greater or less. Yet he soon discovered that on clear nights dew was not always formed with equal freedom. Not only were there differences apparently depending on the relative dryness of the air, but others, which he was unable to explain, were noticed. The cause of these peculiarities will be given further on. Wells noticed also that the quantity of dew was less when the woolpacks were near any object which hid a portion of the heavens. He tried the following experiment:—Placing a board on four props, he put one piece of wool on the board, another under it. He found that though both pieces of wool were equal in weight, each weighing ten grains, the uppermost on a clear night gained 14 grains in weight, while the lowest gained but 4. Again,

he made a curved pasteboard roof over one of his woolpacks, and he found that on a night when the protected piece gained but two grains in weight, a piece placed on the top of the pasteboard gained no less than 16 grains

Next, making experiments on the temperature of the air near his woolpacks, he found that where dew was most freely formed the air was coldest Dr Wilson of Glasgow had asserted that the formation of dew is a process producing cold But the experiments made by Muschenbrock and those who followed him, had shown conclusively that dew is the consequence, not the cause of cold We know, indeed, that the condensation of aqueous vapour is a process during which heat and not cold is given out (See *Dew-Point*)

But seeing, thus, that the formation of dew is caused by a diminution of the temperature of the air, Wells set himself to inquire what his experiments taught as to the way in which the air becomes cold He no longer inquired, for example, why dew was not formed under a pasteboard cover, while above the cover dew was copiously formed, but why the air, under such a cover, was not as cold as the air above it

He was thus led to the formation of his famous theory of dew, respecting which Dr Tyndall remarks that "it has stood the test of all subsequent criticism, and is now universally accepted"

Dr Wells's explanation of the phenomena of dew is founded on this general principle, that dew results from the condensation of the aqueous vapour of the atmosphere, on substances which have become cooled by the radiation of their heat

All the phenomena of dew admit of being explained by this principle Thus it had been noticed that plates of metal were often dry when dew was copiously deposited on wood or grass This is at once seen to depend on the well-known fact that metals are bad radiators of heat, so that the temperature of a metal plate, exposed in the open air at night, is higher than that of grass or wood similarly circumstanced Dew does not form freely on gravel for a similar reason On glass, which is a good radiator, dew forms freely The astronomer is often troubled by this quality of glass, for on clear nights the object glass of his telescope will become covered with dew The way in which this is prevented affords an illustration of the fact already noticed by Wells, that the mere concealing of a part of the heavens by an opaque screen will prevent the formation of dew If a cylinder of card or tin is placed on the end of the tube, no dew is formed. The reason is, that the radiation of heat from the glass is checked In the same way, of course, the facts observed by Wells are explained The wool under the pasteboard cover did not radiate its heat into space like the wool placed on the top of the cover Dr Wells remarks on this fact, and the consequences which flow from it —"I had often, in the pride of half knowlege, smiled at the means frequently employed by gardeners to protect tender plants from cold, as it appeared to me impossible that a thin mat, or any such flimsy substance could prevent them from attaining the temperature of the atmosphere, by which alone I thought them liable to be injured But when I had learned that bodies on the surface of the earth become, during a still and serene night, colder than the atmosphere, by radiating their heat to the heavens, I perceived immediately a just reason for the practice I had before deemed useless"

It will be seen, further, how completely Wells's theory accounts for the two facts that dew is seldom formed in cloudy weather, or when there is much motion in the air We see that in one case the clouds form a screen, checking the process of radiation, while, in the other, the motion of the air, by bringing continually fresh air to the neighbourhood of objects which are radiating their heat into space, prevents those objects from lowering the temperature of a definite portion of the air around them

It remains only to be noticed, that the circumstance that in equally clear weather dew is not always formed in equal quantities, is due to the fact that, when the air is clear, there may yet be aqueous vapour in its upper regions in quantities sufficient to check the radiation of heat

Dr Tyndall remarks that, though valuable facts have been accumulated respecting dew by Mr Glaisher, M Martins, and others, little has been added to the theory of dew since Dr Wells completed his researches

DEW-POINT The degree of temperature at which the vapour in the air begins to be condensed as the air cools (See *Hygrometer*) The determination of the dew point is a matter of great importance to the meteorologist By comparing the dew point with the actual temperature of the air he can tell the relative humidity of the air He knows that at the actual temperature the air would be saturated if it contained a certain quantity of moisture, while he knows also that the actual quantity present is only such as would suffice to saturate air at the observed dew-point, the ratio of this last quantity to the former expresses the relation between the actual humidity of the air and the humidity of saturation at the observed temperature The dew-point in the evening further shows the temperature near to which the minimum

during the night is likely to be For when the temperature has fallen so as to reach the dew point, the aqueous vapour in the air will be condensed, and in this process a certain quantity of heat will be set free which will raise the temperature of the air Then the temperature will again sink by radiation slightly below the dew point, dew will be deposited and the temperature will again be raised, and so on through the night, without any fall of temperature far below the dew-point

DEXTRIN, or, *British Gum* A gummy substance produced by the action of heat, diastase, or acids upon starch. It owes its name to its property of rotating the plane of polarisation to the right (*dexter*, right) (See *Circular Polarisation of Liquids*) Its composition is the same as starch, $C_6H_{10}O_5$, it possesses a light brown colour and a peculiar odour, resembling that of toasted bread, it does not crystallise, and has the appearance of Gum Arabic, it dissolves in water, and is largely used in the arts and manufactures. Postage stamps are rendered adhesive by means of dextrin

DEXTROGYRATE AND LÆVOGYRATE See *Right and Left-handed Polarisation*

DEXTROSE See *Sugar*

DIAGOMETER (διαγω, to conduct, μέτρον, a measure) An instrument invented by M Rousseau for measuring the conducting power of oils He used it as a method of examining their purity It consisted of a dry pile, by means of which a current was passed through the oil, and the strength of the current determined by a magnetised needle Want of conducting power, of course, diminished the current, and therefore the deviation of the needle

DIACAUSTIC See *Caustic*

DIACTINIC (δια, through, and ακτιν, a ray) Transparent to the actinic or chemical rays of light (See *Actinism*)

DIAL The dial or sun dial is a contrivance for determining the time by means of the shadow of a straight rod on a plane surface The essential principle of the dial is that the rod shall point to the pole of the heavens Since the apparent motion of the sun due to the earth's rotation carries him round the polar axis of the heavens at a rate appreciably uniform, the plane through the sun and the rod must turn uniformly round the latter, and thus at any given hour of solar time on one day the shadow of the rod will have the same position on any plane as at the same hour of solar time on another day It only requires, therefore, that a correction should be made for the *equation of time* (*q v*), in order that, from the indications of the dial, the civil or mean solar time should be deduced (See *Day*)

DIALYSER The parchment paper or *septum*, stretched over a gutta percha ring used in the operation of *Dialysis*

DIALYSIS (διαλυσεs, δια, through, and λυω, to loose) During his experiments on the diffusion of liquids, Professor Graham discovered that solutions of certain bodies pass through membranes with considerable facility, whilst others pass through very slowly He soon found that the former class embraced bodies which were of a crystalline character, such as metallic salts, and organic bodies, such as sugar morphia, and oxalic acid, whilst the latter class consisted of bodies devoid of crystalline power, such as gum, albumen, gelatine, &c He therefore gave to one class, consisting of easily diffusible substances, the name of *crystalloid*, and to the other the name of *colloid* Amongst the crystalloids alcohol is classed, and amongst the colloids many soluble oxides, which are in an uncrystalline modification, such as hydrated soluble silicic acid, soluble sesquioxide of iron, soluble alumina, &c The most convenient dividing film or *septum*, as the discoverer named it, is made of *parchment paper* A sheet of this substance is stretched over a gutta percha hoop, and its edges are well drawn up and confined by an outer hoop, it is then allowed to float on a basin of pure water, and in it is poured a mixed solution of colloid and crystalloid Diffusion commences at once, the crystalloid rapidly passes through and dissolves in the pure water beneath, whilst the colloid for the most part remains behind Professor Graham gave this process of separation the name of *dialysis*, and it is now in constant use in chemical laboratories for effecting separations which would be extremely difficult, if not impossible, by other processes Thus, gruel or broth, containing a very little arsenic (*arsenious acid*), dissolved in it and submitted to dialysis, gives up the whole of its arsenic to the pure water, whilst scarcely a trace of the organic substances pass through The arsenic can be detected with the greatest facility in the water, although if it had remained mixed with the great excess of organic matter, its separation and detection would have offered considerable difficulties In cases of suspected poisoning the course now generally pursued is to pour the whole contents of the stomach, or other liquid which the analyst has to examine, upon a *dialyser*, and after allowing it to stay there for twenty four hours to examine the aqueous solution Almost all the poisons in common use, such as *arsenic*, *strychnine*, *corrosive sublimate*, *oxalic acid*, *acetate of lead*, *morphia*, (the active agent in laudanum and opium), being *crystalloids*, easily pass through, and the work of the toxicologist is very much simplified, as he has only an aque

ous solution of a comparatively pure substance to deal with, instead of a highly complex mixture of organic substances If urine is dialysed and the aqueous solution evaporated and extracted with alcohol, pure urea is obtained in beautiful white crystals (See *Parchment Paper*, *Diffusion of Liquids*.)

DIALKALAMIDES See *Amides*

DIAMAGNETIC (διά, through) A term due to Faraday, and first used by him in describing his discovery of the action of magnets on light He defined it then to mean "a body through which the lines of magnetic force are passing, and which does not by their action assume the usual magnetic state of iron or loadstone" (*Phil Trans* 1846) But before long he had proved the action of magnets upon all bodies, had called them all *magnetic*, and divided them into two classes, *paramagnetic* and *diamagnetic*, according to their action in and upon a magnetic field In experimenting optically upon heavy glass, as described in the article above referred to, he was attracted by an action which he observed of the magnet on the glass itself He had a bar of glass suspended horizontally between the poles of a powerful electro magnet, and he found that on making connection with the battery, and thus producing a magnet, the bar of glass, if it were out of this position, immediately swung round and placed itself with its longer axis across the line joining the poles of the electro magnet, or, *equatorially*, (he calls the line which joins the poles the *axial*, a line perpendicular to it the *equatorial* line) The bar on being displaced from this position swings back to it again, and after a few oscillations comes to rest as before It thus takes a position perpendicular to the lines of force and at right angles to that which would be taken by a similar bar of iron or nickel, these being in stable equilibrium in the axial direction, that is, parallel to the line joining the poles of the magnet If the bar of glass was placed nearer to one pole than to the other, it set as before equatorially, but it was also found to be repelled from the nearest pole, and if it was placed a little to one side of the axial line it was driven farther from this line, and turned with its length perpendicular to the lines of magnetic force The effects were very similar when one pole of the magnet was made to act alone on the body, and the repulsion was well manifested on using a ball or a cube of glass instead of an elongated bar He then proceeded to examine a large number of other bodies of all kinds, simple and compound, organic and inorganic, transparent and opaque, and he gives a list of fifty six in his first paper on the subject (*Phil Trans* 1846, p 21), all of which he found to be acted on by the magnet, and all in the same way as the heavy glass Liquids and gases were enclosed in tubes and thus examined The conclusion he came to after a long series of experiments was this, that all bodies are acted on by the magnet, and may be divided into two classes, those which are affected like iron and nickel, which are attracted by the magnet and set axially, and those which are affected like heavy glass, which are repelled by the magnet and set equatorially, and these he subsequently called *paramagnetic* and *diamagnetic*, respectively, and *he showed that the motions displayed by diamagnetic bodies in a magnetic field are all reducible to one simple law, namely that the particles of the diamagnetic tend to move into the positions of weakest magnetic force*

Of the large number of bodies he examined he found that the greatest parts were diamagnetic, he tested a large number of crystals, rock crystal, sulphate of calcium, sulphate of barium, alum, &c Of organic bodies, liquid and solid, alcohol, ether, wax, caoutchouc, blood, mutton, beef, leather, apples, bread, also water, sulphuric acid, hydrochloric acid, and many others, and found these diamagnetic, he also examined the metals, and of these he added a few to the magnetic class, which already contained iron, nickel, and cobalt, namely, platinum, palladium, titanium, manganese, cerium, chromium, and osmium The others, bismuth, antimony, zinc, &c, were found diamagnetic He proved also that in whatever state a body is, whether simple or compound, it still produces the same effect Thus, in the case of a compound each of the elements of which it consists produces its own effect, and the result obtained from the body depends on whether the magnetic or the diamagnetic part, if there be both, preponderates

On examining still farther, it appears that there is still a condition to be taken account of—namely, that which depends on the medium in which the body is placed To determine the effect of it, Faraday made use of the law which we have just mentioned—that each component of the body produces its own effect He found that sulphate of iron is strongly paramagnetic, and knowing that water is diamagnetic, he was able to produce three solutions of different strengths, with which he proceeded with the following experiment —Filling glass tubes with each of the solutions, he found that they all pointed axially—that is, exhibited paramagnetic properties when suspended in air He then took vessels containing the solutions, and suspended the tube in these solutions under the influence of the magnet Each tube when in its own solution was quite indifferent, or pointed slightly equatorially, owing to the diamagnetic property of the glass of which it was constructed, but on suspending them in the other solutions, it was found that a tube suspended in a solution weaker than that which it contained was para-

magnetic, a tube suspended in a solution stronger than its own was diamagnetic. It appeared, then, that the explanation of the phenomenon must stand in this way, that all bodies have a tendency to move into the stronger parts of the magnetic field, but that some have more power than others, and that any body is paramagnetic or diamagnetic according as it is surrounded by a medium whose power is weaker or stronger that that of the body itself.

He then proceeded to examine gases, and here at first he was unsuccessful, for he could obtain no result but a negative one—namely, that gases and a vacuum are not different in power. The difficulty was, that he required to enclose the gas in a glass tube, which, being diamagnetic itself, and of large mass compared with the mass of all the gas, rendered the effect produced by the gas insensible. Afterwards, however, he returned to the subject, and by driving a stream of gas towards the poles, he found that, in the case of oxygen, the stream turned axially, and was attracted into the axial line; but all other gases he examined were diamagnetic. It appears, however, probable, from the later experiments of Graham, that hydrogen is paramagnetic. On examining the gases again in glass tubes, with the assistance of a torsion balance, Faraday was able to compare the magnetic powers of the various gases, and the powers of the same gas under different conditions, as to pressure and temperature.

Some farther information on this subject will be found under our article on *Magnetism*, and the list of the order of bodies as to magnetic power determined by Faraday is given there. For full information on this subject, however, the papers of Faraday himself, ought to be consulted. They are published in the Philosophical Transactions, from 1846 onward, and reprinted in vol. iii. of his Experimental Researches. (See also *Diamagnetism* by Professor Tyndall.)

DIAMETER, APPARENT. (διά, through, and μετρον, a measure.) The apparent diameter of a heavenly body is the angle that body subtends as viewed from the earth.

DIAMIDES. See *Amides*.

DIAMINES. See *Amides*.

DIAMOND. (Corrupted from αδαμας, αδαμαντος, adamant, from α, not, and δαμαω, to break.) Pure carbon in a transparent crystalline form, and the hardest substance known (10 on Mohr's scale). (See *Hardness of Minerals*.) Specific gravity, 3.5 to 3.6. It is generally colourless, but sometimes tinged red, orange, yellow, green, or blue. The index of refraction is 2.439, being exceeded only by chromate of lead and orpiment. (See *Index of Refraction*.) It is unaffected by any liquid, and infusible at the highest attainable temperature. Before the oxy-hydrogen blowpipe it gradually burns away, and the same takes place when it is heated white hot, and plunged into an atmosphere of oxygen, carbonic acid being produced. When exposed to the intense heat of the voltaic arc, the diamond becomes converted into graphite. Besides its value as a gem, it is of great use in the arts and manufactures. Diamond dust is used for cutting and polishing other gems; the edge of a native crystal is used by glaziers for cutting glass; a sharp point is used for scratching and engraving on glass; a splinter is also used as a tool for turning glass lenses in a lathe; and rough diamonds, too imperfect to be used as gems, are mounted as boring tools for perforating rocks. Many attempts have been made to prepare diamonds artificially, but hitherto they have been unsuccessful.

DIAPHANOUS. (διαφανης—δια, through, and φαινω, to shine.) Transparent; allowing light to pass through.

DIASTASE. A white amorphous substance soluble in water. It is extracted from malt, and is the substance to which that body owes its property of converting starch into dextrin. (See *Dextrin*.)

DIATHERMANCY. (δια, through; θερμη, heat.) A term employed by Melloni to designate the property of transmitting radiant heat. It therefore corresponds to *transparency* in the case of light, and the expression "transparent to heat-rays" is occasionally employed. If we have a source of heat placed near a thermometer, a rise of the mercury will be produced; if now a thin plate of rock-salt is introduced between the source and the thermometer, the mercury will fall but slightly, because the rock-salt permits nearly all the heat from the source to pass through it, in virtue of its diathermancy; but if a plate of the same thickness of selenite or amber is placed between the source and the thermometer, a very marked difference will be observed, nearly all the heat will be cut off, and the thermometer will therefore indicate a very slight rise of temperature, because selenite and amber possess very slight diathermancy, that is, they are more or less *opaque* to heat rays. Rock-salt is said to be a *diathermanous substance*, while selenite and amber are called *athermanous substances* (α, not, θερμη, heat,) but this latter term is not much used because all substances allow a certain amount of radiant heat to pass through them. The following table shows the diathermancy of various solids to radiant heat from different sources. The total radiation from each source was first measured by a thermo-electric pile, and delicate galvanometer; a plate of the substance one tenth of an inch thick was then introduced between the face of the pile and the source of heat, and the diminution

of transmitted heat (as shown by a decreased deflection of the needle of the galvanometer), was noted

TABLE SHOWING THE TRANSMISSION OF RADIANT HEAT, EMANATING FROM DIFFERENT SOURCES, THROUGH VARIOUS SOLIDS OF A UNIFORM THICKNESS Total radiation = 100 The following numbers show the percentage of the total radiation transmitted (*Melloni*)

Names of substances employed Thickness = 2 6 millimetres, ($\frac{1}{10}$ inch)	Locatelli lamp	Incandescent platinum	Copper at 400° C	Copper at 100° C
Rock salt,	92	92	92	92
Sicilian sulphur,	74	77	60	54
Fluor spar,	72	69	42	33
Beryl,	54	23	13	0
Iceland spar,	39	28	6	0
Glass,	39	24	6	0
Rock crystal (transparent),	38	28	6	3
,, ,, (smoky),	37	28	6	3
Chromate of potash,	34	28	15	0
White topaz,	33	24	4	0
Carbonate of lead,	32	23	4	0
Sulphate of baryta,	24	18	3	0
Feldspar,	23	19	6	0
Violet amethyst,	21	9	2	0
Artificial amber,	21	5	0	0
Borate of soda,	18	12	8	0
Green tourmaline,	18	16	3	0
Common gum,	18	3	0	0
Selenite,	14	5	0	0
Citric acid,	11	2	0	0
Tartrate of potash,	11	3	0	0
Natural amber,	11	5	0	0
Alum,	9	2	0	0
Sugar candy,	8	1	0	0
Ice,	6	0 5	0	0

We notice in the above table that with the exception of rock-salt, the diathermancy varies with the nature of the source of heat, and this arises from the fact that heat rays vary in quality with the nature of the source (See *Quality of Heat*) Thus luminous heat rays have a shorter wave length than obscure heat rays We must specially bear in mind, therefore, that the above results obtain only with regard to the sources of heat there mentioned, rock salt, the most diathermic substance of all, has been found by Prof Balfour Stewart to be very athermic or opaque to rays issuing from its own substance, in fact a thick plate was found to stop three fourths of the heat radiated from a thin plate of heated rock salt Transparency for light has nothing to do with transparency for heat, thus, clear rock crystal which is transparent to light, and smoky rock crystal which is opaque, are almost equally diathermic, and transparent sugar and ice cut off far more heat than opaque sulphur and sulphate of baryta Again the solution of iodine in bisulphide of carbon used by Tyndall in his experiments on calorescence, is absolutely opaque to light, while it is extremely diathermic in regard to radiant heat Melloni also determined the diathermancy of various liquids, but as he employed glass cells to contain them, the radiant heat was considerably influenced by means external to the liquid itself Tyndall employed cells of rock-salt and a different source of heat (See *Absorption of Heat*)

Thickness has a considerable effect on diathermancy, as on transparency In the case of light we know that many things—glass, and water, for instance, when seen in a thin layer, appear absolutely colourless, whereas when we look through a considerable thickness they are seen to be distinctly coloured, because an absorption of certain light rays has taken place within the mass of the substance, which a thin layer of that substance could not effect It is thus also in regard to radiant heat, a thick layer of a substance is less diathermic than a thin layer In the above table the uniform thickness was 2 6 millimetres, by diminishing this thickness a less amount of heat is absorbed, and hence a greater amount is transmitted, on the other hand, by increasing the thickness a greater amount of heat is absorbed, and a less amount transmitted A thin plate of glass may be as diathermanous as a thick plate of rock-salt, and this proves that the absorption of heat like that of light takes place within a substance, not alone at its surface Pouillet gives the following table to show the influence of thickness on diathermancy The intensity of the incident beam is represented by 100, thus, if a thickness of 0 5 millimetre of glass allows 77 5 per cent of the total radiation from a Locatelli lamp to pass through it, a thickness of 5 0 millimetres allows 62 0 per cent of the total radiation

Comparing colza oil at thicknesses of 0.5 millimetre, and 200 millimetres, we observe that about twelve times as much heat is transmitted through the former thickness than through the latter, or, otherwise expressed, that the absorption by the layer of 200 millimetres in thickness, is twelve times greater than that of the layer of 0.5 millimetre, while water in layers greater than 11 millimetres in thickness does not transmit any of the heat, emitted from an incandescent spiral of platinum wire. It is noticeable in the case of glass, that after a certain limit has been passed, an increase of thickness does not appear to diminish the transmission.

TABLE SHOWING THE INFLUENCE OF THICKNESS ON THE DIATHERMANCY OF SUBSTANCES

Thickness of layers in millimetres	Thickness in inches	Glass (S Gobain)			Colza Oil		Water	
		Locatelli lamp	Incandescent platinum	Copper at 400° C	Locatelli lamp	Incandescent platinum	Locatelli lamp	Incandescent platinum
0.5	0.019	77.5	62.1	14.4	64.0	32.0	25.1	8.7
1.0	0.039	73.3	51.5	9.9	48.3	22.8	19.3	5.7
1.5	0.058	70.4	46.1	6.7	41.0	18.7	16.0	4.2
2.0	0.078	68.2	42.8	5.0	36.1	16.3	13.9	3.2
2.5	0.097	66.0			32.7			
3.0	0.117	65.3	38.3	2.9	30.6	13.6	11.4	2.0
4.0	0.156	63.4	35.8	2.0	27.8	12.0	10.0	1.5
5.0	0.195	62.0	34.0	1.5	25.7	10.8	9.1	1.1
6.0	0.234	60.9	32.3	1.4	23.9	9.8	8.6	1.0
7.0	0.273	60.0	30.9	1.2	22.6	8.9	8.2	0.8
8.0	0.312	59.2	29.7	1.1	21.8	8.1	8.0	0.6
9.0	0.351				21.2	7.5	7.8	0.5
10.0	0.39				21.0	7.1	7.7	0.4
11.0	0.429				20.9	6.7	7.7	0.3
50.0	1.95				12.5	2.1	2.4	0.0
86.0	3.354							
100.0	3.90				8.1	1.2	1.3	
150.0	5.85				6.1		0.7	
200.0	7.80				5.3			

See also *Absorption of Heat*

DIATHERMOMETER (*δια*, through, *θερμη*, heat, *μετρέω*, to measure). An instrument devised by Prof. Guthrie for determining the thermal resistance of liquids. It consists of an air thermometer terminated above by a brass cone faced with platinum, having its base uppermost, and in a perfectly horizontal plane; the base of a second cone of precisely the same area can be approximated to the cone of the air thermometer, and between the opposite bases the liquid to be examined is introduced. Now if we have a constant source of heat in the upper cone (such as a current of water of known and invariable temperature), it is obvious that by varying the liquids between the cones, and noting the effect in a given time on the column of liquid in the air thermometer, we can obtain results (comparable among themselves), of the relative thermal resistance of the various liquids employed. (See also *Conduction of Heat*.)

DIATOMIC ALCOHOLS. See *Alcohols, Series of*

DICHROIC CRYSTALS. Sir David Brewster (*Optics*, page 250) gives a table of the colours which certain dichroic crystals exhibit when examined in polarised light, from which the following list is taken:—

	Optic axis in plane of Polarisation	Optic axis in plane perpendicular to that of Polarisation
Uniaxial Crystals—		
Sapphire	Yellowish green	Blue
Ruby	Pale yellow	Bright pink
Emerald	Yellowish green	Bluish green
Blue beryl	Bluish white	Blue
Green beryl	Whitish	Bluish green
Quartz yellow.	Yellowish white.	Yellow
Amethyst	Blue	Pink
Tourmaline	Greenish white	Bluish green
Rubellite	Reddish white	Faint red
Idocrase	Yellow	Green
Mellite	Yellow	Bluish white
Lilac apatite.	Bluish	Reddish
Olive apatite.	Bluish green	Yellowish green

	Optic axis in plane of Polarisation	Optic axis in plane perpendicular to that of Polarisation
Uniaxial Crystals—		
Phosphate of lead.	Bright green	Orange yellow
Iceland spar	Orange yellow	Yellowish white
Octohedrite	Whitish brown.	Yellowish brown
Biaxial Crystals—		
Blue topaz	White	Blue
Green topaz	White	Green.
Greenish blue topaz.	Reddish gray.	Blue
Pink topaz	Pink	White
Pink yellow topaz.	Pink	Yellow.
Yellow topaz	Yellowish white.	Orange
Yellowish purple		
Sulphate of baryta	Lemon yellow	Purple
Yellow sulphate of baryta	Lemon yellow	Yellowish white
Orange yellow sulphate of baryta.	Gamboge yellow.	Yellowish white
Cyanite	White	Blue
Dichroite	Blue	Yellowish white
Cymophane	Yellowish white	Yellowish
Olive green epidote	Brown	Sap green
Whitish green epidote.	Pink white	Yellowish white
Mica	Reddish brown.	Reddish white

(See *Dichroism*)

DICHROIC MICROSCOPE A double image prism is sometimes attached to a compound microscope, so as to form two images of a crystal or other substance in the field of view, and enable it to be examined for dichroism (See *Dichroscope*, *Dichroism*)

DICHROISM (δις, two, and χρῶμα, colour) A property which some crystals possess of appearing of two different colours where light passes through them in different directions If three colours are produced it is called trichroism, and, if more, polychroism The general property is termed pleochroism The crystals of the double chloride of palladium and potassium appear of a deep red colour along the axis, and of a vivid green in a transverse direction A similar phenomenon is observed in the mineral iolite or dichroite The phenomenon of dichroism depends upon the fact that the absorption of light is regulated by the inclination of the incident ray to the axis of double refraction, and on a difference of colour in the two pencils formed by double refraction —(*Sir D Brewster*) Examined in the dichroscope many natural and artificial crystals are seen to possess the property of dichroism (See *Dichroic Crystals*, *Dichroic Microscope*)

DICHROITE, or, *Iolite* A mineral so named by Haüy on account of certain optical properties which it possesses (See *Dichroism*) It occurs in prisms belonging to the trimetric system, it appears deep blue in the direction of the principal axis, and brownish yellow, or yellow gray at right angles to it Chemically considered it is a silicate of magnesia, alumina, and iron, and is sometimes used as a gem

DICHROSCOPE An instrument devised by Haidenger for examining the property of *dichroism* It consists of an achromatised double image prism of Iceland spar, fixed in a brass tube, having a small square aperture at one end, and a convex lens at the other, of such a power as to give a sharp image of the square hole On looking through the instrument this hole appears double, and if a dichroic crystal be placed in front of it the two images will appear of different colours By causing the tube to revolve, the colours alternately disappear and appear, in this manner *dichroism* may be detected in crystals by viewing them in one direction only A dichroscope is frequently combined with the polarising apparatus of a microscope (See *Dichroic Microscope*)

DIDYMIUM (διδυμος, a twin) A rare and unimportant metal, occurring with cerium and lanthanum It was discovered by Mosander in 1841 The name owes its origin to the resemblance of the metal to lanthanum, and the difficulty of separating the two Symbol Di. Atomic weight, 48 It forms a *protoxide* (Di_2O), and a *peroxide* of undetermined composition, the protoxide is a powerful base, and forms salts with acids which possess a rose or violet colour

DIELECTRIC (διὰ, through) Any medium through or across which static induction takes place is called by Faraday a *dielectric* In his Experimental Researches, vol i, he considers the part which the dielectric plays, with respect to two conductors between which induction is taking place, and he proves that its function is not merely the passive one of presenting a medium across which the electricity cannot pass, but that the inductive influence is

transmitted from particle to particle of the dielectric, each molecule of it in any line connecting the two surfaces being polarised, that is electrified positively on one side, and negatively on the other Hence he was led to the idea that some dielectrics may transmit the electric influence with more facility than others, and may assume the polarised condition with greater or less intensity On examination this turned out to be the case, and hence arose his discovery of *Specific Inductive Capacity* (See *Induction, and Capacity, Specific Inductive*)

DIFFERENTIAL SCREW, HUNTER'S So named from the principle of its action, depending on the difference between the size of the threads of two screws The distance between the threads of a screw, on which its mechanical effect depends, cannot be indefinitely diminished without so diminishing the strength of the machine as to make it practically useless Hunter's machine is a contrivance for increasing the power of the screw without greatly diminishing the strength of the threads It consists of two screws, with threads differing but little in thickness, the smaller working within the other When the inner screw rises the larger screw is made to descend Thus, during one revolution, the entire movement is equal only to the difference between the height of the threads, and consequently the board or other surface used in compression passes through a much smaller distance than in a simple screw press, but exerts a proportionately increased pressure on the substance compressed

DIFFERENTIAL THERMOMETER This instrument consists of two glass bulbs containing air, and separated from each other by a narrow tube in which there is a column of mercury or sulphuric acid The tube is usually bent into the form of an U, the two bulbs being uppermost The bulbs contain the same quantity of air, and if they possess the same temperature the air in each will obviously possess the same degree of elasticity, and the included column of liquid will be at rest midway between them If now one of the bulbs be heated, the air within it will be expanded, and its pressure will be greater than that in the other bulb, hence the liquid will move from the warmer to the cooler bulb It is equally obvious that however high the temperature may be, if both bulbs equally possess it, there will be no motion of the liquid column It is essentially a differential action, caused by the difference in the amount of heat possessed by the two equal volumes of air A very rude instrument of this nature is mentioned by J C Sturmius in his *Collegium Experimentale sive Curiosum* (1676), but the instrument as described above was invented by Sir John Leslie, and described in 1804 in his "Experimental Enquiry into the Nature and Propagation of Heat" Count Rumford somewhat modified the instrument by largely increasing the size of the bulbs, shortening the length of the connecting tube, and employing a very short column of liquid as an index In both Leslie's and Rumford's thermometer the movement of the liquid is indicated by a graduated scale, and since gases expand far more than solids or liquids, for the same amount of heat, this instrument is infinitely more sensitive than mercurial or alcohol thermometers It has been estimated that by its means a change of not more than the 6,000th part of a degree of Fahrenheit can be indicated Formerly the differential thermometer was much used for researches on radiant heat, but the invention of the thermo electric pile by Nobili, and its application to the measurement of infinitely small temperatures by Melloni, has caused this latter instrument to be now universally employed for researches on radiant heat, and for all delicate measurements such as Lord Rosse's recent experiments on the heat of the moon, and those of Messrs Huggins and Stone on the heat of the stars The differential thermometer is still useful for lecture experiments, and a recent improvement of it by Professor Matthiessen has greatly increased its adaptability to this purpose (See also *Thermometer*, *Air Thermometer*)

DIFFRACTION (*Diffrango*, *dis*, apart, and *frango*, to break) A disturbance of the straight path of a ray of light occasioned by its passage close to the edge of an opaque body The phenomenon is best observed by holding a pin in a beam of divergent light, and allowing its shadow to fall on a sheet of white paper The shadow will not be sharp and black, but will be surrounded by luminous fringes tinted with the colours of the spectrum, the centre, where the black shadow should be, being a luminous line as if the pin were transparent The explanation of this is simple the rays of light *inflected* in passing along one edge of the pin meet the rays inflected by the other edge, and interfere, producing alternate increase and diminution of wave length, and giving rise to coloured fringes if ordinary light is used, or alternate bands of light and dark if homogeneous light is employed, the centre always being luminous If the conditions are reversed, and the divergent light passes through a small hole in a plate of metal, the same phenomena of interference are observed between the rays passing direct through the aperture and those inflected obliquely by the edges, the central portion in this case being a black patch corresponding in shape and size to the opening, and surrounded as before with coloured fringes Experiments in diffraction may be varied in an almost endless manner by having holes of different sizes and shapes, or by arranging several near together (See *Fringes*)

DIFFRACTION SPECTRA. By arranging the apparatus for diffraction experiments, in

such a manner that the coloured fringes are produced of considerable size, and of the utmost attainable purity of tint, a series of very beautiful spectra are produced, in which the principal Fraunhofer lines are seen The best arrangement for this purpose is to pass sunlight through a narrow slit, and adjust a telescope to distinct vision of the slit A very fine grating is now placed over the object glass, the bars being parallel with the slit This changes the appearance of the slit altogether, in the centre a luminous line is seen, while almost unchanged on each side is a broad black band, and beyond this stretch away a series of spectra overlapping each other Those nearest the centre are the most perfect, and show the Fraunhofer lines to greatest perfection, and they gradually fade away on each side into darkness (See *Fraunhofer's Lines*)

DIFFUSION COEFFICIENTS. Beilstein (Ann Ch Pharm, xcix 165) has given the following table of diffusion coefficients. The temperature being 6°C (42 8°F), the strength 4 per cent, and chloride of potassium taken as unity —

Names of Salt	Diffusion Coefficient	Names of Salt	Diffusion Coefficient
Chloride of Potassium .	1 0000	Sulphate of Potassium .	0 6987
Nitrate of Potassium .	0 9487	Carbonate of Sodium .	0 5436
Chloride of Sodium	0 8337	Sulphate of Sodium	0 5369
Bichromate of Potassium	0 7543	Sulphate of Magnesium	0 3587
Carbonate of Potassium	0 7371	Sulphate of Copper .	0 3440

DIFFUSION OF HEAT (*Diffundo*, to spread abroad) Heat is readily reflected from polished metallic surfaces, and the angle of incidence of the rays is equal to the angle of reflection but there is also a certain oblique reflection whereby some of the heat is diffused, and, so to speak, scattered in different directions irregularly

DIFFUSION OF LIGHT When parallel or divergent rays of light, as from the sun or a candle, fall upon a sheet of white paper, unglazed porcelain, ground glass, or bodies having a similar surface, they are diffused in all directions, as if the surface were self luminous

DIFFUSION OF GASES The intermixture of two gases which are free to communicate with one another When two gases, of different densities, are mixed, they do not separate in consequence of gravity, as liquids do Thus although oxygen is sixteen times as dense as hydrogen, yet if the two gases be mixed, they will not separate however long they may be allowed to remain at rest Again, when two gases are separated by a porous membrane, an interchange of particles takes place through the membrane, until ultimately the composition of the mixture on both sides is the same, but the rapidity with which the interchange is effected is different with different gases These are the two main features of the phenomenon of diffusion The laws regulating the nature and the rapidity of the intermixture have been fully investigated by Graham and may be illustrated by the following experiments Two jars filled with different gases, as, for example, oxygen and hydrogen, are connected by means of a long glass tube passing through perforated corks The jar of hydrogen is placed uppermost In the course of a few hours the oxygen will ascend to the upper jar, and the hydrogen will descend to the lower Ultimately both jars will contain a mixture in the same proportion, which will continue uniform and permanent The same result will take place with any other gases or vapours which do not act chemically on one another

As a second experiment, let a glass vessel be filled with oxygen gas, tied over with a membrane, and placed under a bell jar of hydrogen The gases will diffuse through the porous membrane, but, after an interval of an hour or more, it will be found that the volume of hydrogen which has passed into the smaller vessel, is greater than the volume of oxygen which has passed outwards, and the membrane will, in consequence, be distended outwards If the small vessel be filled with hydrogen, and the bell-jar with oxygen gas, the membrane will be concave instead of convex, showing that in this case, as in the first, more hydrogen has passed through the membrane outwards, than oxygen gas inwards

The rates of diffusion of different gases may be compared by means of a diffusion tube This is a graduated tube, 10 or 12 inches long, closed at one end by a dry plug of plaster of Paris, or compressed plumbago If the tube be filled with hydrogen, and the open end be placed in a vessel of mercury, so that the surface of the mercury, within and without the tube, stands at the same level, it will be found that the mercury in the tube will immediately begin to rise, in opposition to gravity, and that, in a few minutes, it will stand several inches higher within than without Hydrogen will have passed out of the tube, and air will have entered through the porous plug, but the passage of the former will have been much more rapid than that of the latter By experiments similar to this, made with different gases, Graham has determined the rates of gaseous diffusion, and has found that the diffusion volume of a gas is in the inverse

proportion to the square root of its density Thus, in the second experiment described above, since the densities of hydrogen and oxygen are as one to sixteen, and the square root, therefore, as one to four, four times as much hydrogen would pass through the membrane as oxygen The density of air is to that of hydrogen as 1 0692, and the square roots, therefore, as 1 2632, hence, in the third experiment, for every volume of hydrogen which passed out 2632 volumes of air passed in, or for every measure of air passed in (1 by 2632) or 3 7994 measures of hydrogen passed out Hence, if air be taken as unity, Graham's law gives the diffusion volume of hydrogen as 3 7994 Actual experiment gives 3 83 The following table gives the results of calculation and experiment, in the cases of several important gases —

Gas.	Density Air = 1	Square Root of Density	$\frac{1}{\sqrt{\text{Density}}}$	Diffusion Volume from Experiment
Hydrogen . . .	0692	2632	3 7994	3 83
Marsh Gas . .	559	7476	1 3375	1 344
Carbonic Oxide . .	968	0 9837	1 0165	1 015
Nitrogen . .	971	0 9856	1 0147	1 014
Olefiant Gas . .	978	0 9889	1 0112	1 019
Oxygen	1 1056	1 0515	0 9510	0 949
Sulphuretted Hydrogen	1 1912	1 0914	0 9162	0 95
Nitrous Oxide .	1 527	1 2357	0 8092	0 82
Carbonic Acid . .	1 529	1 2365	0 8087	0 812
Sulphurous Acid . .	2 247	1 4991	0 6671	0 68

When a mixture of gases is introduced into the diffusion tube, each preserves the rate of diffusion peculiar to itself, so that a partial mechanical separation of two gases of different densities, which are mixed, may be effected by diffusion If two gases have the same temperature, and be heated through the same number of degrees, the relation of their densities remains unaltered, consequently the relative rates of diffusion also remain the same, but since the density of each is diminished by a rise of temperature, the rate of diffusion is accelerated The increase in the velocity of diffusion is not, however, proportional to the increase of volume due to the rise of temperature, the second being more rapid than the first, consequently a given weight of gas will be diffused more quickly at a lower than at a higher temperature (Graham, Phil Mag, 1833, vol ii, p 352, 1840, vol i, 1846, pp 574, 591, 1849, p 349, 1863, pp 385, and 405)

DIFFUSION OF LIQUIDS When a glass phial, containing a saline solution is gently introduced into a larger vessel containing water, or a solution of different density from the first, in such a manner that they do not immediately mix, diffusion gradually takes place, and, after a certain time, depending on the nature of the liquids, the temperature, and the degree of concentration, the liquid inside and outside the glass phial will be identical in composition These phenomena were first minutely investigated by Professor Graham (See Phil Trans 1850, 1862 Journal of the Chem Soc iii 60, 257, iv 83, and xv 216) With crystalline bodies it has been found that different salts, in solutions of equal strength, diffuse unequally in equal times, and the rate of diffusion increases with the temperature, the general law for one salt being that the velocity with which a soluble salt diffuses from a stronger into a weaker solution is proportional to the difference of concentration between two contiguous strata The rate of diffusion coincides in many cases, the groups being identical with those of isomorphous bodies Thus hydrochloric, hydrobromic, and hydriodic acids diffuse at equal rates, and the same rule holds good with the chlorides, bromides, and iodides of the alkaline metals, with the sulphates of magnesium and zinc, &c Some bodies—namely, those classed by Graham as *colloids*—diffuse with extreme slowness Thus taking the time required for a certain amount of hydrochloric acid to diffuse, as unity, the following table exhibits the time required for the same quantities of other substances —

Hydrochloric acid, . . .	1	Sulphate of magnesium,	7
Chloride of sodium, .	2 33	Albumen, ...	49
Sugar, ...	7	Caramel	98

The two latter substances are colloids Diffusion takes place with great regularity through a *septum* of bladder, or, preferably, *parchment paper*, and this principle has been applied by Professor Graham as the foundation of a most important branch of analysis for the separation of different substances, to which he has given the name of Dialysis, (*q v*)

DIGESTER See *Papin's Digester*

DIMINUTION OF LIGHT OF GAS BY ADMIXTURE OF AIR. Dr Frankland

gives the following table in his lectures on coal gas, delivered before the Royal Institution of Great Britain in the spring of 1867 —

Substance burnt	Illuminating power	Substance burnt	Illuminating power
Pure gas,	100	Gas with 8 per cent of air,	42
Gas with 1 per cent of air,	94	" 9 "	36
" 2 "	89	" 10 "	33
" 3 "	82	" 15 "	20
" 4 "	74	" 20 "	7
" 5 "	67	" 30 "	2
" 6 "	56	" 40 "	0
" 7 "	47		

Thus, when coal gas is burnt with an admixture of 40 per cent of atmospheric air, it ceases to be luminous, in fact, the particles of carbon which exist in an ordinary flame, and by their incandescence render it luminous, are now oxidised in the flame, and we obtain a flame similar to that afforded by a Bunsen's burner, that is, of great heating power, but no luminosity

DIPHDA (Arabic) The star β of the constellation Cetus

DIP, MAGNETIC, is the angle which the direction of a magnetised needle, free to move in the plane of the magnetic meridian, makes with the horizontal plane at the place Let a magnetised needle, free to turn in a vertical plane, be placed so that that plane may coincide with the plane of the magnetic meridian, it will be found that in most localities one end or other will *dip* downward, and thus the direction of the needle will make a certain angle with the horizontal plane at the place This angle is called the *angle of dip*, or the *magnetic dip* For example, in England, a needle so placed dips its north end downwards, and the angle of dip is about 68° At all places north of a certain line, called the *magnetic equator*, at which the dip is zero, and which lies near to the geographical equator, the north end of the needle dips downwards, and the angle increases as we go northwards The same is the case south of the magnetic equator, except that the south end of the needle dips downward (See also *Magnetism, Terrestrial*)

DIP OF THE HORIZON The angle which a line drawn from the eye to the apparent horizon makes with the plane of the rational horizon The earth being a sphere, if the eye is raised above the earth's surface, a line from the eye to the apparent horizon—that is, to the farthest visible point of the earth in any direction—is a tangent to the earth at that point On the other hand, the plane of the rational horizon is a tangent plane to the earth at the point vertically below the observer Thus it is easily seen that the dip of the horizon is equal to the angle between the vertical at the observer's station, and the vertical at the farthest visible point of the earth Here no account has been taken of the irregularities of the earth's surface Refraction also affects the apparent dip of the horizon (See *Refraction, Atmospheric*)

DIPPING-NEEDLE An instrument for measuring the angle of *dip* or *magnetic inclination* at a given place—that is, the angle which a magnet, free to move about a horizontal axis, and placed in the magnetic meridian, makes with the horizontal plane

The dipping needle consists of a light magnetised bar, supported by a horizontal axis, and thus capable of turning in a horizontal plane The axis is either a fine knife edge, resting on an agate plate, or a delicate steel wire on friction rollers The axis is at the centre of a vertical graduated circle, and the point of the needle, or of an index attached to it, moves over the graduations, so that the inclination of the needle to the horizontal plane can be read off by means of them This vertical circle is supported on a short vertical pillar, which turns round its own axis at the centre of a horizontal graduated circle, the pillar carries an arm which is furnished at its extremity with a vernier and clamping screw, and the vernier moves over the divisions of the horizontal circle A three legged support, having levelling screws at its feet, completes the instrument

To use the instrument, it is first carefully levelled, and the vertical circle is then turned round upon its pivot till the needle stands vertical When this is the case, the only force acting upon it is the vertical component of the earth's magnetism, and we know that in this case the plane of the circle in which it swings must be at right angles to the magnetic meridian, which we thus determine This done, the circle containing the magnet is turned through 90° exactly, by means of the vernier moving on the horizontal circle beneath Thus the needle will be free to move in the plane of the magnetic meridian It will take up a certain position inclined at an angle, depending on the locality, to the horizontal plane This angle is read off on the graduated circle, and is the magnetic dip or inclination at the place of observation

DIRECT MOTION OF A COMET A comet is said to have direct motion when it travels round the sun in the same direction as the planets

DIRECTION OF FORCE When a force acts upon a point at rest, the direction of the force is the line along which the point would commence to move if it were free to do so, when only one force acts upon a point the direction of the force is the direction of motion Direction is one of the properties of forces which can be represented by straight lines, and on this account it is sometimes termed a geometrical property (See *Graphic Representation of Forces*)

DIRECTIVE FORCE The action of the earth upon a magnetised needle is generally spoken of in these terms For the influence of the earth upon the magnet is simply *directive* It tends to place the axis of the magnet in a certain line, but there is no force of translation, that is, no tendency to make the magnet move bodily from place to place This may be shown experimentally by placing a magnetised needle on a piece of cork floating on water The needle, and the cork with it, turns round so that it points north and south, but it only turns about its centre, and does not move either northward or southward But if another magnetised bar be brought near to the needle, not only does it give it a definite direction, but it also exerts upon it an attractive force which makes the needle move bodily towards the bar The reason is that in the latter case the attracted pole is sensibly nearer than the repelled pole, and hence the force of attraction exerted upon the needle preponderates (See *Attraction, Magnetic*) In the case of the earth, on the other hand, the length of any needle or bar is so short compared with the distance of the needle from the centre of the earth's magnetic force, that both poles of the needle are sensibly at the same distance from that point, hence the force of attraction exerted on one pole is equal to the force of repulsion exerted on the other pole, and there is no tendency in the magnet to move one way more than another. The force exerted upon the needle is of the nature of a *couple* (see *Couple*), and the tendency to turn the magnetic axis into a certain line is measured by the moment of the couple, that is, the product of the number which expresses the length of the bar and the number which expresses the absolute force exerted on either end The latter depends upon the intensity of magnetisation and on the position of the bar on the earth's surface (See *Magnetism, Magnetism, Terrestrial*)

DIRECT VISION PRISM See *Prism, Direct Vision*

DISC (δίσκος, a round plate) A term applied to the visible surface of the sun, the moon, or a planet

DISCHARGE When an electrified body loses its electricity and returns to its normal unexcited state, it is said to be *discharged* There are various ways in which discharge may take place

(*a*) *Disruptive Discharge*, which consists in the breaking through of the insulating medium which surrounds the charged body This occurs in three forms—the *discharge by a spark*, the *brush discharge*, and the *silent* or *glow discharge* The phenomena of disruptive discharge were investigated very completely by Faraday in connection with his theory of induction (Exp Researches, ser xii, Phil Trans 1838) Harris (Phil Trans 1834) examined the laws for the electric spark The best way of observing the spark is between a small ball, about an inch in diameter, and one very much larger, one of them is electrified positively by means of a good electric machine, and the other connected with the earth On turning the machine, keeping the balls from one to two inches apart, bright sparks may be seen passing, accompanied by a sharp report like the cracking of a whip At this distance the sparks appear to pass straight between the two balls, and to the unprotected eye look like lines of fire of considerable thickness If the distance between the balls be increased beyond two inches the spark takes a branching form, having a root upon the smaller ball, and extending with lateral forks towards the larger ball The direction, too, of the sparks is crooked and irregular With a Winter's machine, furnished with a large ring, sparks may be obtained from twelve to fourteen inches long, which, when viewed in a darkened room, show beautiful branches and offshoots The appearance of the sparks depends somewhat upon whether the large or the small ball is electrified positively The distance which the sparks will pass depends upon the quantity of electricity upon the balls, and also upon the nature and condition of the insulator or dielectric which is between them, the kind of electrification of the balls also affects it Harris showed that the quantity on the charged ball required to produce a spark varies directly and simply with the distance between the balls and that, the quantity remaining the same, the distance at which a spark will pass is greater as the density of the air between the balls is less, or, the distance remaining the same, the quantity required to produce sparks varies directly with the density of the air Faraday showed that the nature of the gas likewise affects the production of a spark, and that not on account of the density of the gas He showed that hydrogen has very little insulating power, that hydrochloric acid gas has nearly three times the insulating power of hydrogen, nearly twice that of oxygen, and is considerably higher than that of nitrogen, which again stands higher than oxygen Faraday also found that the colour of the electric spark depends

upon the medium through which it passes. Thus, in air it is of a well-known purplish white. In nitrogen gas the purple or red colour is more powerful than in air. In oxygen and in carbonic acid the spark is very white, while in hydrogen its colour approaches crimson.

The *Brush Discharge* is thus described by Faraday. He produces it by attaching to the prime conductor of an electric machine a metal rod, 0.3 of an inch in diameter, and terminated by a rounded end or small ball; and, if necessary, bringing near to it some large conducting surface. "The brush," he says, "was obtained by a powerful machine on a ball about 0.7 of an inch in diameter, attached to the positive prime conductor—a short conical bright part or root appeared at the middle part of the ball, projecting directly from it, which, at a little distance from the ball, broke out suddenly into a wide brush of pale ramifications, having a quivering motion, and being accompanied at the same time with a low dull chattering sound. On using a smaller ball the general brush was smaller, and the sound though weaker more continuous." The nature of the gas in which the brush occurs is found to influence the appearance of it. In nitrogen the brush is very easily obtained, and it is remarkably fine in form, colour, and in the light exhibited. In oxygen the brush is close and compound, and not so brilliant. In hydrogen it is better than in oxygen, the colour of it is greenish gray; while in carbonic acid gas and in hydrochloric acid gas it is difficult to obtain a brush at all.

When a thinner metallic rod than that described as above, such as 0.2 in. or even less in diameter terminated by a conical point, is attached to the prime conductor of an electric machine, the *glow discharge* is obtained. It consists of a silent steady flame playing around the point of the rod accompanied by powerful currents of air proceeding from it. If the air around the point be rarefied, either by means of the air pump or by heating, the glow may be obtained much larger and finer in respect of light. In both the brush and glow discharge the appearance is considerably altered if the negative conductor of the electric machine be used instead of the positive or prime conductor.

As we have already mentioned, in all these cases a breaking down of the molecular arrangement of the particles of the dielectric accompanies the disruptive discharge. Induction precedes the discharge, and by it the molecules are thrown into a strained or polarised state (see *Induction*); when the strain becomes too great to be any longer sustained, a subversion of the molecules takes place, and discharge is the consequence.

(β) *Conductive Discharge*. When an electrified body is touched by a conductor connected with the earth, or more generally when two points having a difference of electric potential, as for instance the two ends of a voltaic pile or battery, are joined by means of a conductor a passage of electricity, according to common phraseology, or a *discharge*, takes place: this is called *conductive discharge*, or discharge by *conduction*. Particulars on the subject will be found under *Conductor*, *Conduction*.

(γ) There is, lastly, discharge by *convection* or *convective discharge*. When an electrified body is surrounded by a gas, the particles of the gas, continually moving from place to place, come in contact with the electrified body; each little particle becomes charged and repelled from the body, and thus carries away a portion of the electricity. This is *convective discharge*. Coulomb, in investigating the laws of the distribution of electricity upon conductors, was obliged to take into account the loss sustained by his conductors standing charged for some time in air. He showed that the *quantity lost by convection in a given time is proportional to the charge of the conductor*.

DISCHARGER. An instrument used for discharging a Leyden jar, an electric battery or other condenser, in order to avoid the danger of allowing the charge to pass through the body of the experimenter. It consists of two bent brass wires connected together by a joint at one end, the other extremities being furnished with knobs of brass; thus by means of the joint the knobs may be placed at different distances from each other. At the joint there is a glass handle, by means of which the tongs may be held, glass being a non-conductor of electricity.

DISCHARGER, UNIVERSAL. An apparatus much used in connection with Leyden batteries or heavily charged condensers. On a convenient stand are placed two glass pillars which are surmounted by universal joints, and through each of these passes a moveable brass rod, one end of which bears a ring for convenience of attachment to the battery, and the other a knob. Between these knobs is a small ivory table, the height of which can be altered at pleasure, and on which may be placed any object through which it is wished to pass an electric discharge.

DISPERSION (*Dispergo, dispersus—di*, asunder; and *spargo*, to scatter.) The dispersion of light is its separation into coloured rays by passage through a prism; the amount of dispersion varies with the substance of the prism. (See *Dispersion, Coefficients of*.)

DISPERSION, COEFFICIENTS OF. When a ray of light is passed through a prism, it suffers besides refraction, dispersion, *i.e.*, it is separated into its component colours. But for

the same amount of refraction different media disperse these colours differently, and the difference between the indices of refraction of the fixed lines B and A produced by a refracting medium is called its coefficient of dispersion, or simply its dispersion

The following table of Coefficients of Dispersion is an abstract of one given by Sir D Brewster, in his "Treatise on Optics," page 372-374

Substance	Coefficients of Dispersion	Substance	Coefficients of Dispersion
Oil of cassia,	0 089	Beryl,	0 022
Phosphorus,	0 156	Ether,	0 012
Bi sulphide of carbon,	0 077	Selenite,	0 020
Balsam of Peru,	0 058	Alum,	0 017
Oil of bitter almonds,	0 048	Castor oil,	0 018
Oil of anise seed,	0 044	Crown glass, green,	0 020
Oil of cumin,	0 033	Gum Arabic,	0 018
Oil of cloves,	0 033	Water,	0 012
Oil of Sassafras,	0 032	Citric acid,	0 019
Rosin,	0 032	Glass of borax,	0 018
Rock salt,	0 029	Garnet,	0 018
Caoutchouc,	0 028	Chrysolite,	0 022
Flint glass,	0 026	Crown glass,	0 018
Do, another sample,	0 029	Plate glass,	0 017
Oil of juniper,	0 022	Sulphuric acid,	0 014
Nitric acid,	0 019	Tartaric acid,	0 016
Canada balsam,	0 021	Nitre,	0 009
Cajeput oil,	0 021	Borax,	0 014
Oil of poppy,	0 022	Alcohol,	0 011
Zircon,	0 045	Sulphate of baryta,	0 011
Hydrochloric acid,	0 016	Rock crystal,	0 014
Gum copal,	0 024	Borax glass, 1 bor 2 silica,	0 014
Nut oil,	0 022	Blue sapphire,	0 021
Oil of turpentine,	0 020	Chrysoberyl,	0 019
Felspar,	0 022	Blue topaz,	0 016
Amber,	0 023	Sulphate of strontia,	0 015
Calcspar, greatest,	0 027	Hydrocyanic acid,	0 008
Diamond,	0 056	Fluor spar,	0 010
Oil of olives,	0 018	Cryolite,	0 007
Gum mastic,	0 022		

DISPERSION, EPIPOLIC See *Fluorescence*

DISPERSION, FALSE See *Fluorescence*

DISPERSION, INTERNAL See *Fluorescence*

DISPERSION, IRRATIONALITY OF It has been found that two substances, when made into prisms, may produce spectra of equal lengths, but in one, oil of Cassia for instance, the blue end is more expanded than the red end, whilst in the other, sulphuric acid for instance, the red end is more expanded than the blue This phenomenon is called the irrationality of dispersion, and must be taken into account in the formation of achromatic lenses (See *Achromatism*)

DISPERSION, PARTIAL See *Partial Dispersion*

DISPLACEMENT OF LIQUIDS If we take a vessel exactly brimful of water, and totally immerse in the water a body which is neither soluble in the water nor penetrable by it, it is clear that the body displaces a volume of water equal to its own volume, and that the volume of the water, which overflows, is equal to the volume of the body immersed Again, if the water be contained in a vessel (say cylindrical) of sufficient capacity to receive the body without an overflow resulting, the water will rise higher and higher in the cylinder, as the body sinks beneath its surface until it is wholly immersed In order that the body may be immersed, an equal volume of water must be lifted, in other words, the weight must be overcome of a volume of water equal in volume to the body Consequently, whenever a body is immersed in a liquid, it is pressed upwards by a force equal to the weight of the liquid it displaces Whether, therefore, a body will sink or rise when plunged into the midst of a liquid, depends upon whether the weight of the body is greater or less than the weight of an equal volume of the liquid If the former is the case the body will sink in the liquid, but the force with which it sinks, that is, its weight in the liquid, must be less than its weight *in vacuo*, because it is pressed upwards by a force equal to the weight of the liquid displaced Its

sinking force is therefore equal to its original weight, *minus* the weight of an equal volume of liquid If the body be lighter than an equal volume of liquid it will, if it have the same size as the one previously considered, be drawn to the earth by a less force than before, but it will be pressed upwards by a force equal to the upward force in the former case, namely, the force equal to the bulk of the displaced liquid The upward force will now be greater than the downward one, and the body will rise with a force equal to the difference of the two forces acting on it, which will, in this case, be the weight of a volume of liquid equal in volume to the body, *minus* the weight of the body The force with which such a body rises is called its *buoyancy* If a body, which is lighter that an equal volume of water, be held so as to touch the surface of the water, and then let go, it will sink until it floats, or, if the same body be allowed to rise from a state of total immersion, until it floats, it will attain a position of equilibrium in which only a portion of it is immersed, that is, below the horizontal surface of the liquid In this state of equilibrium the upward and downward forces must be equal The second is the actual weight of the body, the first is a force equal to the weight of the liquid displaced These principles collectively constitute the "*Principle of Archimedes*" The same principle becomes more clear from another method of consideration Imagine a vessel of liquid to be at rest Conceive any volume in it (say a cubic inch) to be isolated from the rest by six rigid walls, without thickness and without weight It is self-evident that isolation of this kind would not influence the equilibrium either of the included or excluded portion We know, however, that the inclosed portion is being acted on by gravity, and urged down by its own weight Since, however, it is at rest, this downward tendency must be counteracted by an equal and opposite force In other words, the cubic inch must be pressed upwards by a force equal to the weight of a cubic inch of the liquid If, now, we imagine the rigid cubic inch to be emptied of liquid, we disturb the condition of equilibrium by removing one of the opposing forces Consequently, the cubic inch will rise with a force equal to the weight of a cubic inch of liquid If now this rigid, empty, weightless cubic box be filled with olive oil, it will indeed, be pressed down by the weight of that cubic inch of oil, but it will be pressed upwards as before, by a force equal to the weight of a cubic inch of liquid (say water) Now a cubic inch of water weighs more than a cubic inch of olive oil, consequently the cube of oil will rise with a force equal to the difference of these two weights If, however, the rigid empty cube be filled with mercury, it will be pulled down by a force greater than the weight of a cubic inch of water, and will still be pushed upwards by a force equal to the weight of a cubic inch of water It will, therefore, sink with a force equal to the difference between the weights of a cubic inch of mercury and a cubic inch of water.

DISSECTED JAR, or *Jar with Moveable Coatings* Is used to show that in a charged Leyden jar the electricity is distributed upon the surface of the dielectric, and not upon the coatings It consists of a glass jar, whose shape is that of a truncated cone, furnished with coatings of thin brass plate, or of tinfoil pasted upon a form of card board The stem which carries the knob of the jar is firmly attached to the bottom of the inside coating, and is generally turned into a hook at the top, so that by means of it the inside coating may, if necessary, be lifted out on a rod of glass When the jar is to be used it is charged, t inner coating is then removed by means of a glass rod otherwise it may be set on a insulating stool, and removed by the hand The glass jar is then lifted out of the outer coating The coatings may be handled or applied to the electroscope, and afterwards replaced, when it is found that the electricity had not left the jar with them, the jar being still charged

DISSIMULATED ELECTRICITY A term used to denote those parts of the electric force in the outside and inside coatings of a Leyden jar or other condenser which act inductively towards each other in contradistinction to the portion which may be made to act towards external objects The *dissimulated electricity* cannot be discovered by means of the proof plane, or by an electroscope (See *Charge, Free*, and Faraday's *Exp Research*, ser xiv)

DISSIPATION OF ELECTRICITY The gradual loss of electricity, which a charged conductor surrounded by non-conductors, sustains by means of them, is spoken of as the *dissipation of the charge* However good the arrangements for insulation may be, there is always a slow loss of electricity, and this, in the matter of determining the laws of attraction and repulsion, and of the distribution of electricity upon the surface of conductors becomes a matter of very high importance Coulomb, in his investigations of those laws, arranged his experiments so as to diminish as much as possible the loss by dissipation, and he then examined the reasons for the loss which his conductors still sustained, and the amount of it

There are two chief causes of loss in the case of bodies insulated by being supported upon an insulator, and surrounded with air In the first place the insulating support is never perfect Coulomb found that glass stems are excessively bad insulators This is due to the thin invisible film of moisture which always collects over them, unless they are in an artificially dried atmos-

phere The insulating power of a glass stem is very much improved by varnishing it thinly over with shell lac dissolved in spirits of wine Moisture does not adhere with anything like the same readiness to a glass rod treated in this way For light bodies Coulomb found that thin stems of shell lac drawn out make the best support

The second cause of loss is that due to the air itself The molecules of air in contact with the conductor become charged, and therefore repelled from the body They thus, by degrees, carry away the electricity of the body, the amount lost in a given time depends upon the quantity of electricity with which the conductor is charged, and diminishes as the charge gets weaker and weaker, according to logarithmic law (See also *Discharge*)

DISSOCIATION (*Dis*, apart, *socius*, a companion) A term first employed by Ste Claire Deville, to express a partial decomposition which takes place when chemical compounds are exposed to a very high temperature, thus, when a rapid current of steam is passed through a white hot platinum tube, some of it is decomposed, and an explosive mixture of oxygen and hydrogen can be collected by passing the mixed vapour and gases into water, carbonic acid may likewise be decomposed, by transmission through a white hot porcelain tube filled with fragments of porcelain, into a mixture of carbonic oxide and oxygen, and by a modification of the apparatus Deville has further decomposed carbonic oxide into carbon and oxygen, which unites with a further quantity of carbonic oxide to form carbonic acid Sulphurous acid, under similar circumstances, may be resolved into sulphur and sulphuric acid, and in the presence of cold metallic silver hydrochloric acid is decomposed into its elements The decomposition of water into its elements may readily be effected by throwing a lump of white hot platinum into it, a copious evolution of steam takes place, and along with this bubbles of permanent gas are seen to rise, which, on being collected, proved to be mixed oxygen and hydrogen gases From these experiments it is seen that the force of chemical combination appears to be suspended by great heat, so that at a high temperature like that of the sun we may imagine that chemical elements, such as oxygen, hydrogen, chlorine, potassium, &c, can exist in the gaseous state, intimately mixed, but chemically uncombined

DISSONANCE, or DISCORD See *Beats*

DISTILLATION (*Distillo*, to drop down slowly) An operation by which a liquid is converted into vapour by heat, which vapour is condensed by cold in a separate vessel It may be employed for various purposes, thus simple distillation purifies liquids, it enables a more volatile to be separated from a less volatile substance, by its means a liquid possessing a definite boiling point may be separated from other liquids possessing other boiling points This latter is known as *fractional distillation*, and is much used in the separation of hydrocarbons, the various products being collected at intervals of, say ten degrees of temperature *Destructive distillation* is a term applied to the distillation of solid organic matter without access of air, &c, usually on the large scale, when various gaseous and liquid products result, thus coal and wood are submitted to destructive distillation on the large scale, and the products in each case are most numerous, and of varying compositions The essential parts of a distilling apparatus are a vessel in which the substance is heated, called sometimes a *still*, and sometimes a *retort*, a *condenser* or *refrigerator*, in which the vapour is cooled, and a *receiver* in which the condensed products are collected Distillation was an important operation in the earliest alchemical processes of which we have any record, it does not, however, appear to have been known before the time of Pliny

DISTRIBUTION, ELECTRIC See *Electrostatics*

DIURNAL ABERRATION See *Aberration of the Celestial Bodies.*

DIURNAL ROTATION OF THE EARTH See *Earth, Day*

DIVERGING RAYS (*Dis*, asunder, and *vergo*, to incline) These are rays which start from one point, and spread outwards as they advance Light from a candle consists of diverging rays, as they diverge their intensity diminishes inversely as the square of the distance from the point of emission The point whence they emanate is called the radiant point

DIVING BELL The materiality of air was demonstrated by Anaximenes, who inverted a vessel, closed at one end, and pressed it under water with the mouth downwards No air was seen to enter, because air is matter, and it is impossible for two kinds of matter to exist in the same space This experiment may easily be tried by depressing a tumbler, mouth downwards, into a pail of water, and if a cork has been previously included within it, the upper surface will be found to be dry when the tumbler is taken from the water This illustrates the principle of the diving bell, which is a contrivance for enabling persons to descend and remain below the surface of water It is usually of a bell shape, hence the name The earlier diving bells were not supplied with air from above, from which cause the diver could not remain long under water, as the air in the bell soon became vitiated, and unfit for respiration In 1788, Smeaton added a force-pump to the diving bell, by which means air could be pumped into the bell from

above, and the diver could remain for a length of time under water Various improvements connected with raising and lowering the bell, supplying it with air, and with light, removing the foul air, &c, were introduced by Spalding, and by the Swedish engineer, Triewald The diving bell is much used for recovering property from wrecks, and for all under-water operations connected with the foundations of bridges, &c

DIVISIBILITY The property common to all substances, by which they may be divided into particles of unlimited minuteness, each of which possesses the qualities of the original mass All bodies probably consist of ultimate particles or molecules, but by no process of science or art have the ultimate constituent atoms which admit of no further subdivision been obtained

DOG DAYS See *Canicular Days*

DOG STAR See *Sirius*

DOLOMITE A compact and granular variety of magnesian limestone, a double carbonate of magnesia and lime

DORADO (The *Sword-fish*) One of Bayer's southern constellations Half of the greater Magellanic Cloud falls within this constellation

DOUBLE CONCAVE PRISM See *Prismatic Lens*

DOUBLE CONVEX PRISM See *Prismatic Lens*

DOUBLE DECOMPOSITION, PRIMARY TYPES OF According to Dr Odling —

$H'Cl'$	Chloride or Hydride	$Cl'Cl'$	$Na'Cl'$	$Et'Cl'$
$\left.\begin{matrix}H\\H\end{matrix}\right\}O''$	Oxide or Hydrate	$\left.\begin{matrix}Cl\\H\end{matrix}\right\}O''$ $\left.\begin{matrix}Cl\\Cl\end{matrix}\right\}O''$	$\left.\begin{matrix}Na\\H\end{matrix}\right\}O''$ $\left.\begin{matrix}Na\\Na\end{matrix}\right\}O''$	$\left.\begin{matrix}Et\\H\end{matrix}\right\}O''$ $\left.\begin{matrix}Et\\Et\end{matrix}\right\}O''$
$\left.\begin{matrix}H\\H\\H\end{matrix}\right\}N'''$	Nitride or Amido	$\left.\begin{matrix}H\\H\end{matrix}\right\}N'''$ $\left.\begin{matrix}I\\I\\H\end{matrix}\right\}N'''$ $\left.\begin{matrix}Cl\\Cl\\Cl\end{matrix}\right\}N'''$	$\left.\begin{matrix}Na\\H\\H\end{matrix}\right\}N'''$ $\left.\begin{matrix}\\ \\H\end{matrix}\right\}N'''$ $\left.\begin{matrix}Na\\Na\\Na\end{matrix}\right\}N'''$	$\left.\begin{matrix}Et\\H\\H\end{matrix}\right\}N'''$ $\left.\begin{matrix}Et\\Et\\H\end{matrix}\right\}N'''$ $\left.\begin{matrix}Et\\Et\\Et\end{matrix}\right\}N'''$
$\left.\begin{matrix}H\\H\\H\\H\end{matrix}\right\}C''''$	Carbide or Methide	$\left.\begin{matrix}Cl\\H\\H\\H\end{matrix}\right\}C''''$ Cl_2H_2C'''' Cl_3HC'''' Cl_4C''''	$\left.\begin{matrix}Na\\H\\H\\H\end{matrix}\right\}C''''$	$\left.\begin{matrix}Et\\H\\H\\H\end{matrix}\right\}C''''$

DOUBLE IMAGE MICROMETER This consists of an eye piece of four lenses, one of which is cut in half, each semi-lens being fixed in a frame connected with screw adjustment and graduated scale When the two semi-lenses are together in the position they occupied before they were cut, only one image is seen, and the graduated scale should mark zero, but when the semi lenses are moved parallel to their line of division, the single image divides into two, each of which follows the movement of the semi lens which forms it By separating the axis in this manner until the opposite sides of the image, (the moon or a planet, for instance,) touch, and observing the scale micrometer, observations can readily be made See *Micrometer*, *Dynameter*, *Double Image*

DOUBLE IMAGE PRISM. See *Prism, Double Image*

DOUBLE REFRACTION Under the head of polarisation, the phenomena of double refraction by Iceland spar are explained Few crystals possess this property in a sufficiently high degree to show two images The polariscope is, however, a very delicate test for this property, and when examined in it, many crystalline and other bodies are seen to be doubly refractive Amongst these may be mentioned horn, scales of insects, many animalculæ, gelatine, unannealed glass, starch grains, hair, sections of bone, &c Even a piece of glass which is free from double refraction is seen to assume this property when it is submitted to a strain either of pressure, or torsion If this property is not strong enough by itself to produce colour, a thin film of selenite may be employed to intensify it (See *Polarised Light*)

DOUBLE REFRACTION, POLARISATION BY. See *Polarisation, Plane.*

DOUBLE STARS See *Stars, Double*

DOUBLET A simple form of microscope first proposed by Dr Wollaston. It consists of two plano-convex lenses whose focal lengths are in the proportion of one to three The lens of shortest focus is placed next the object, and the convex sides are turned towards the eye See *Microscope*

DOUBLE TOUCH A technical term applied in practical magnetism to a method of magnetisation, in which a pair of powerful bar magnets are held, inclined to the bar to be magnetised, and with their unlike poles touching it and very nearly touching each other, and in this position are drawn backwards and forwards from end to end, and finally lifted off in the middle Magnetisation by double touch was invented by Mitchell and perfected by Epinns See *Magnetisation*

DOUBLY REFRACTING CRYSTALS See *Crystals, Double Refraction of*

DRACO (The Dragon) A large Northern constellation, one of Ptolemy's It follows a winding course around the Lesser Bear This constellation is interesting as containing a star which has been supposed to have been the first pole star recognised by astronomers This orb, Alpha Draconis, once far brighter than at present, would seem to have been near the place of the northern pole at the epoch when the great pyramid was constructed A long inclined passage within that structure has a position indicating that about 2000 years before the Christian era, the star Alpha Draconis must have been visible from the lower end of the passage (and therefore in the day-time as well as by night) at its lower meridional passage Draco contains a planetary nebula (close by the pole of the ecliptic,) which was the first whose gaseity was detected by Mr Huggins

DROPS The size of a drop furnishes data for determining the relative cohesions of two liquids That size depends, (1) Upon the attraction of cohesion of the liquid , (2) Its adhesion to the matter upon which the drop is formed , (3) The shape of the matter from which the drop moves , (4) The physical relation of the medium through which the drop moves on the one hand, to the liquid of which the drop is formed, and on the other, to the matter on which it is formed , (5) The rate at which drops succeed one another The following are the chief conclusions arrived at by Professor Guthrie with regard to the size of a drop under different conditions (Proceedings, R Soc , xiii , pp 444, 457) *Law* 1 The drop-size depends upon the rate of dropping , generally, the quicker the succession the greater the drop The slower the rate, the more strictly is this the case This law depends upon the difference, at different rates, of the thickness of the film from which the drop falls *Law* 2 The drop size depends upon the nature and quantity of the solid which the dropping liquid holds in solution If the liquid stands in no chemical relation to the solid, in general the drop-size diminishes as the quantity of solid contained in the liquid increases The cohesion of the liquid is diminished by the dissolved solid *Law* 3 The drop size depends upon the chemical nature of the dropping liquid, and only in a secondary degree upon its density Of all liquids examined, water has the greatest drop size *Law* 4 The drop size depends upon the geometric relation between the solid and liquid If the solid be spherical, the largest drops fall from the largest spheres Absolute difference of radii takes a greater effect upon drops formed from smaller, than upon those formed from larger spheres Of circular horizontal planes, within certain limits (with small planes), the size of the drop varies directly with the size of the plane *Law* 5 The drop-size depends upon the chemical nature of the solid from which the drop falls, and little or nothing upon its density Of all the solids examined, antimony delivers the smallest, and tin the largest drops *Law* 6 The drop-size depends upon temperature Generally the higher the temperature the smaller the drop With water about 86° F a change of 36° F effects small alteration *Law* 7 The nature or tension of the gaseous medium has little or no effect upon drop-size

The above laws apply to a liquid dropping from a solid through a gas If a liquid drops from a solid through a liquid, the drop may ascend or descend, according to the relative densities The following are the general laws observed *Law* 8 The drop size of a liquid which, under like conditions, drops through various media, does not depend wholly upon the density of the medium, and consequent variation in weight in the medium, of the dropping liquid *Law* 9 If there be two liquids, A and B, which drop under like conditions through air, and the drop-size of the one, A, be greater than the drop-size of the other, B , then if a third liquid, C, be made to drop through A and through B, the drop-size of C through A is greater than its drop-size through B *Law* 10 If the drop-size of A through B be greater than the drop-size of A through C, then the drop-size of a fourth liquid, D, through B is also greater than the drop-size of D through C *Law* 11 If a liquid, A, drop under like conditions, in succession, through two liquids, B and C, then its drop-size through any mixture of B and C is intermediate between its drop-size through B and its drop-size through C , and the greater proportion of one

f the constituents in the liquid the more nearly does the drop size of A, through the mixture, pproach to its drop-size through that constituent alone *Law* 12 The drop-size of the mixture f any two liquids, A and B, dropping through a third liquid, C, is intermediate between the rop-size of A through C, and that of B through C, and the greater the proportion of one onstituent in the mixture, the more nearly does the drop-size of the mixture approach to that f that constituent *Law* 13 If the liquid X has a larger drop size than the liquid Y in the iquid Z, then the liquid Z has a larger drop-size in X than it has in Y *Law* 14 If a liquid (has a larger drop size in air than a liquid Y, then the drop size of X through Y is larger han the drop-size of Y through X *Law* 15 If the drop-size of X be greater than the drop-ize of Y in air, and the drop-size of Y be greater than the drop size of Z in air, then the ratio etween the drop sizes of X in any mixture of Y and Z, and the drop-size of that mixture of Y nd Z in X is greatest when the ratio between the drop-sizes of Y and Z is nearest to inity

DRUMMOND LIGHT. (So named from Lieut Drummond, the inventor) See *Lime Light*

DRY PILE This apparatus is an ordinary Voltaic pile, in which the liquid is replaced by ome hygrometric substance, such as paper which has been moistened with sugar and water, nd allowed to dry Zamboni's dry pile, which is one of the most common, is constructed in the ollowing way Paper so prepared is silvered or tinned on one side, and covered on the other with inely ground black oxide of manganese, which, being slightly moistened, may be rubbed on ith a cork From one to two thousand discs of this paper are cut with a punch, and put into glass tube arranged so that the silver of one disc may be in contact with the manganese of he next The tube is closed at each end with a brass cap furnished with a knob The knob t the manganese end is positively electrified, that at the other end negatively A pile, such s we have described, and consisting of 2000 discs, will charge a Leyden jar or condenser The ile lasts for a very long time, often for many years If over dried, however, it loses its power it least temporarily, not recovering it till it has absorbed moisture from the air

DUBHE (Arabic) The star *α* of the constellation Ursa Major It is a variable star

DUCTILITY (*Duco*, to lead, draw out, *ductilis*, capable of being drawn out) A property, elonging chiefly to certain metals, by which they are capable of being drawn out into wire, hat is, of being increased in length and diminished in thickness, without fracture The most luctile substances, with which we are familiar, are gold, silver, platinum, iron, and softened lass Wollaston obtained a platinum wire of 0 00003 of an inch in diameter, by first coating a ine platinum wire with silver, and drawing the cylinder, thus formed, into as fine a wire as possible, and then dissolving the silver in dilute nitric acid By this means a platinum wire was obtained, having a diameter so fine that 1060 yards of it weighed only three quarters of a grain (See *Malleability*)

DUTCH TEARS See *Prince Rupert's Drops*

DYNAM A term proposed by Dr Whewell for the unit of work or dynamical unit See *Dynamical Unit*

DYNAMETER (δυναμις, force, μετρέω, to measure) An instrument for measuring the intensity or magnitude of forces derived from different sources See *Force*, *Spring-Balance*

DYNAMETER, DOUBLE IMAGE In optics an instrument for measuring the power of a telescope It acts by enabling the observer to measure the image of an object glass upon the eye glass The simple dynameter consists essentially of a small compound microscope, containing a graduated scale, which is placed against the eye-piece of the telescope, the image of the object glass is then measured by comparison with this scale The double image dynameter is a similar instrument, but containing two semi-lenses, one of which is moved by a micrometer screw The measurement is here obtained by observing the contacts on opposite sides of the two circular discs representing the object-glass. (See *Double-Image Micrometer*)

DYNAMICAL UNIT A unit adopted in measuring or comparing mechanical forces which produce motion It is usually the force required to lift a given unit of weight In this country the units adopted are the foot-pound, and the horse-power, in France the kilogrammetre, and the cheval vapeur, (see these terms) Since every resistance can be estimated in pounds, and every space in feet, the force which will overcome a given resistance through a given space can always be measured in foot pounds (See *Foot-Pound*)

DYNAMIC ABSORPTION OF GASES AND VAPOURS. See *Dynamic Heating of Gases*

DYNAMIC HEATING OF GASES When the receiver of an air pump is exhausted cold is produced, as is shown by the deposit of moisture on the inside of the receiver, and by the slight haziness which follows the first few rapid strokes of the pump, moreover, a delicate

thermometer, when placed in the receiver, indicates cold When the air is re-admitted the deposit of moisture disappears, and the thermometer indicates warmth The chilling results from the fact that the air in expanding performs work, and a certain amount of heat is thus removed from the gas, which is no longer able to retain its aqueous vapour, the latter is therefore deposited on the sides of the receiver When air is allowed to rush into the vacuum it strikes against the sides of the receiver, and its motion is converted into heat, hence results the warming, and the disappearance of the deposited vapour The air has been heated *dynamically*, it has been heated by the impact of its own molecules, by the resolution of their motion of translation into the motion of heat

Professor Tyndall, in the course of his experiments on the radiation of heat by gases, used a glass tube closed at both ends by rock-salt plates, and capable of being exhausted by an air pump, it was subsequently filled with any gas or vapour that might be desired, at any given pressure In front of one of the rock-salt plates a very delicate thermopile was placed to indicate the amount of absorption, or radiation of heat, by the gas within the tube On one occasion the tube contained a small quantity of alcohol vapour, and the absorption of heat (issuing from a cube of hot water at the remote end of the tube) by this vapour was considerable On admitting air into the tube the absorption was neutralised, radiation from the vapour took place, and heat was indicated The external source of heat was now omitted, and the apparatus arranged as follows —The glass tube had one end closed by a rock-salt plate the other by a plate of glass, and the thermoelectric pile was placed opposite the rock-salt plate The tube was exhausted as completely as possible, and air then permitted to enter the tube, the air became dynamically heated, and the needle of the galvanometer, connected with the thermopile, moved through an arc of 7° Now air is a very bad radiator of heat, and this indication arose from the heat of the warmed air being radiated from the surface of the tube This was proved by lining the inside of the tube with black paper, when, on repeating the experiment, the needle of the galvanometer moved through an arc of 70°, because the black paper absorbed and radiated more heat than the glass The lining was now removed from the tube, which was exhausted, and nitrous oxide gas was allowed to enter, it became heated dynamically, and the needle of the galvanometer showed a deflection of 28°, proving that nitrous oxide radiates better than air When the tube was exhausted the gas was chilled, and the needle moved through 20° in an opposite direction With olefiant gas the deflection due to heating was 67°, and the deflection due to cooling 40° Tyndall calls the heating of the gas, on entering the vacuum, the *dynamic heating of gases*, the radiation which follows, *dynamic radiation*, and the absorption of heat when the gas is pumped out and chilled by performing work, *dynamic absorption* The following table shows the dynamic radiation of certain gases, in degrees of arc, through which the needle of the galvanometer moved on the first admission of the gas into the vacuous tube The results are obviously relative

DYNAMIC RADIATION OF GASES (*Tyndall.*)

Air	7°	Carbonic oxide	19°
Oxygen	7	Carbonic acid	21
Hydrogen	7	Nitrous oxide	31
Nitrogen	7	Olefiant gas	63

These results agree with those determined by a different method for the same gases

The dynamic radiation of the first four gases is, as we see, very slight, and presumably, as before stated, is the radiation of the heat of the warmed gas by the sides of the tube, but if while we heat any one of these gases dynamically, we mix with it a very small amount of a gas or vapour which is a good radiator of heat, the heated gas transmits its heat through the medium of the vapour, just as in the case of a polished cube containing hot water, which radiates but slightly until its surface is blackened, or rendered rough, or varnished. A small quantity of the vapour of acetic ether was allowed to pass into the exhausted tube described above, now this substance is a powerful absorber and radiator of heat, and when oxygen was allowed to rush into the vacuum, the deflection of the galvanometer needle instead of being 7°, as in the case of the gas alone, was 70°, because the heat of the dynamically heated oxygen had been communicated to the molecules of acetic ether vapour, and by them radiated. Tyndall calls this the *varnishing of a gas by a vapour*, in allusion to the analogous varnishing of a bright metal On exhausting the tube cold was produced, the vapour now absorbed heat from the thermopile, instead of radiating heat upon it, and the needle moved to nearly 45° in the opposite direction—that is, in the direction of cold By this means the following results were obtained, (they are given as before in degrees of arc, through which the needle of the galvanometer was deflected, and are hence strictly relative).

DYNAMIC RADIATION AND ABSORPTION OF VAPOURS (*Tyndall*)

	Radiation	Absorption		Radiation	Absorption
Bisulphide of carbon	14°	6°	Amylene	48°	26°
Iodide of methyl	20	8	Alcohol	50	28
Benzol	30	14	Sulphuric ether	64	34
Iodide of ethyl	34	16	Formic ether	69	38
Methylic alcohol	36	18	Acetic ether	70	43
Chloride of amyl	41	23			

The radiation and absorption are here seen to increase and diminish together, as is the case when a source of heat external to the gas is employed for similar experiments An extremely minute quantity of a good radiator has a greater effect than a large quantity of a bad radiator The vapour of boracic ether exceeds all others as an absorber and radiator of heat The tube employed in the foregoing experiments was perfectly exhausted, and a quantity of boracic ether vapour, equal in pressure to $\frac{1}{100}$th of the atmospheric pressure, was introduced, on admitting dry air into the vacuum the needle of the galvanometer was deflected through 56° of arc by the dynamic heating of the air due to impact, and the dynamic radiation of the heat so generated, by the trace of boracic ether vapour in the tube The tube was again and successively exhausted, until the pressure of boracic ether vapour amounted to $\frac{1}{101,000,000}$th of an atmosphere, the deflection was now 14°, and allowing 7° for the radiation from the interior of the tube from direct warming by the dynamically heated air, we have 7° for the dynamic radiation of a quantity of boracic ether vapour which would have to be increased more than one thousand million fold before its pressure would equal that of the atmosphere Even a quantity of vapour amounting to $\frac{1}{1,157,000,000}$th of an atmosphere furnished a sensible dynamic radiation

DYNAMIC RADIATION OF GASES AND VAPOURS See *Dynamic Heating of Gases*

DYNAMICS (*δυναμις*, force or power) The science which treats of the action of force in producing motion It is a branch of mechanics, and treats of bodies not in equilibrium, as statics treats of bodies at rest Dynamics is divided into two parts—*kinematics*, which investigates the circumstances of mere motion without reference to the bodies moved, the forces producing the motion, or to the forces called into action by the motion, and *kinetics* which investigates the nature and relation of the forces which produce motion

Dynamics has to do with the primary conceptions of space, matter, time, and velocity, each of which admits of numerical estimation by comparison with units arbitrarily chosen, hence dynamics is a science of numbers It is usual to consider the subject in two parts, the dynamics of a particle and the dynamics of a rigid body The science owes its origin to Galileo, to whom is due the law of the acceleration of falling bodies Huyghens added the theories of the pendulum and centrifugal force, and Newton developed the science and applied to it the infinitesimal calculus Further information will be afforded by the following works —Professor Cayley's Report on the Recent Progress of Theoretical Dynamics at the British Association, 1857, Lagrange's Mecanique Analytique, and Poisson's Traité de Mecanique. (See *Acceleration, Central Forces, Falling Bodies, Laws of Motion, Pendulum*)

DYNAMOMETER, CHROMATIC An instrument devised by Sir David Brewster for measuring intensity of force, founded on the phenomena of polarised light (See *Polariscope, Double Refraction*) It consists of a bundle of narrow and thick plates of glass, fixed at each end in brass caps Then when any force is applied to a ring in the centre of the bundle, they assume double refracting properties rendered evident in the polariscope by the production of bands of colour, from the width and intensity of these bands the amount of force can be ascertained.

E

EAR —**The ear as an acoustical instrument** The organ of hearing may be considered in three parts —the external ear, the tympanum or middle ear, and the labyrinth or internal ear The external ear consists of the pinna, the part of the outer ear which projects from the side of the head, and the meatus, or passage which leads to the tympanum The extremity of this passage is closed by a membrane (*membrana tympani*), which therefore separates the external from the middle ear The pinna or auricle is concave, and is thrown into various elevations and hollows, which so reflect the undulations of sound, as to collect and concentrate them within the auditory canal (*meatus auditorius externus*), by which they are conveyed to the middle chamber of the ear.

The middle ear or *tympanum* is a narrow irregular cavity in the substance of the temporal bone, filled with air by means of the *Eustachian tube* from the pharynx or back of the mouth It contains a chain of small bones, by means of which the vibrations, communicated from without to the membrana tympani, are in part conveyed across the cavity to the inner wall of the tympanum These bones have been named from their shape respectively the *malleus*, the *incus*, the *os orbiculare*, and the *stapes* The handle of the malleus descends between the two inner layers of the membrane to a little below the centre, where it is fixed, drawing the centre of the membrane inwards, so as to give it the shape of a shallow cone The inner wall of the middle ear, separating it from the internal ear, is very uneven, presenting several elevations and foramina Near its upper part is a reniform opening (the *fenestra ovalis*) which is occupied by the base of the stapes Above this point is a slightly oval aperture (the *fenestra rotunda*), which is closed by another membrane, and connects the tympanum with a part of the internal ear termed the cochlea

The internal ear or labyrinth is the sentient portion of the organ of hearing It is hollowed out of the petrous portion of the temporal bone It consists of two cavities, the osseous or bony labyrinth, and the membranous labyrinth, the former of which contains the latter The osseous labyrinth is divided into three parts—the vestibule, the semicircular canals, and the cochlea, all of which are lined throughout by a thin membrane, and enclose a clear fluid named perilymph The membranous labyrinth has a general resemblance in form to the complicated cavity in which it is contained, and has, therefore, five parts corresponding to the vestibule, three semicircular canals, and the cochlea It contains a liquid termed endolymph Over this membranous structure the ultimate ramifications of the auditory nerve are spread Thus the conditions necessary to the sensation of hearing are realised The vibrations of the air are collected and concentrated by the external ear, and conveyed to the membrana tympani, they are thence transmitted to the internal ear partly by the air within the tympanum, partly by the chain of bones, and partly by the walls of the cavity The vibrations of the membrane of the fenestræ are then transmitted to the fluid of the labyrinths, and to the auditory nerve, and this nerve transmits its impressions to the brain, and gives the sensation of hearing (For further description see Quain's *Anatomy*, and Bain on the *Human Mind*)

EARTH, THE The globe on which we live, and the third planet in order of distance from the sun The earth travels at a mean distance of 91,430,000 miles from the sun The eccentricity of her orbit, though not sufficient to make its figure appreciably elliptical, yet is such that in perihelion she is 1,533,000 miles nearer to the sun, and in aphelion as much further from him than when at her mean distance The earth's revolution around the sun is accomplished in 365 2564 days (See *Year*) The mean diameter of the earth is 7912 miles, the polar diameter 7898 miles, the equatorial 7926 miles The density of the earth is about $5\frac{1}{2}$ times that of water She rotates once upon her axis in 23h 56m 4s of mean solar time (See *Day*)

The Motions of the Earth The most obvious of all astronomical facts, the apparent diurnal motion of the sun, appears to have suggested in very early times the idea that the earth rotates upon her axis, though, until a comparatively recent epoch the number of those astronomers who believed in the absolute fixity of the earth, largely exceeded the number of those who were bold enough to assert that she is in motion, either on her axis or around the sun And, indeed, it must not be forgotten in forming an opinion respecting the theories of ancient astronomers, that the evidence on which the accepted theories in our day are founded, was for the most part unknown to them The whole system of modern astronomy is founded on evidence of a most complicated character, no one part of the system being separable from the rest So that our belief in the earth's rotation is derived from evidence bearing on the revolution of the earth on the earth's figure, on the law of gravitation, and so on, and in turn the rotation of the earth supplies evidence in favour of each of those other relations

So far as the apparent motions of the heavenly bodies seen from any one station on the earth are considered, there is nothing to prove that the earth is really in motion But when we notice the effects which appear on a change of station, when, extending our researches northwards or southwards, we find the apparent axis of the earth's rotation shifting its position and when voyaging towards the east or west we find the actual progress of the diurnal celestial motions appreciably affected as regards the time of their occurrence, the idea presents itself that the diurnal motion is due to a motion of the earth upon her axis For the evidence adduced when such inquiries have been extended to the whole surface of the earth, proves the earth to be globe-shaped, to be suspended freely in space, to be minute compared with the distances separating her from the celestial bodies, so that the idea is suggested that far more probably this relatively small globe turns on its axis, than that those bodies obviously so distant and presumably so vast, travel each day around the enormous circles which they would have to traverse if their diurnal motions were real.

Then, again, the proof of the earth's rotation depends in large part on the proof of the earth's revolution Observation shows that besides their apparent diurnal motion, the sun and a certain number of the stars have motions upon the celestial sphere, the sun seeming to circle once a year round that sphere, and those particular stars (the planets) seeming to follow looped and twisted paths round the celestial sphere in different periods These motions are found, when carefully studied, to be only explicable in a satisfactory manner by supposing that the earth travels round the sun, and that the sun is likewise the centre of the motions of the planets (See *Ptolemaic System, Tychonic System, Copernican System*, &c) And all question as to the reality of the earth's motion is finally removed when the phenomenon of aberration is considered and understood Now when once it is recognised that the earth is travelling around the sun in a wide orbit once a year, the supposition that she does not rotate on her axis, but that the sun is carried once a day round her becomes altogether absurd and untenable

Yet again, when the rotation of the earth is established, we obtain fresh evidence as to the earth's figure, as will presently be seen

So that our ideas respecting the earth's rotation, revolution, and figure, are associated together in the most intimate manner, through the circumstance that nearly all the evidence we have respecting each relation is either founded on, or else affords, evidence respecting the others

The proofs of the earth's rotation, which are really independent, though numerous and sufficiently convincing to the student of science, are of such a nature as not to appear very striking to the generality of minds There is a minute displacement of the stars due to the earth's rotation, but as, even at the equator, the displacement is but about one-third of a second, it is impossible to render its determination a matter of absolute certainty, as in the case of the aberration resulting from the earth's orbital motion Again it has been shown that bodies which are dropped from a considerable height fall slightly to the east of the point below that from which they were let fall Newton had shown that this should be the case because the point of suspension is at a greater distance from the earth's centre than the surface of the earth But the experiments by which this easterly direction of fall is established are delicate and difficult, and it is only on the average of many experiments that the peculiarity is exhibited, many of the bodies dropped falling north, south, or west of the spot vertically beneath the point of suspension Again, Foucault's experiments with the pendulum and gyroscope (see *Pendulum Experiment*, and *Gyroscope*) serve to prove the fact of the earth's rotation, but the arguments on which the proof rests are not so simple and direct as to be easily made clear to the non mathematician In fact, there is no direct evidence of the earth's rotation which is nearly so satisfactory as the indirect evidence derived from the earth's revolution round the sun

The revolution of the earth is proved, as we have said, by the evidence derived from the aberration of the fixed stars It must be remembered that to the astronomer the displacement due to this cause is not one of those minute quantities which can only be detected by the most delicate observations It has been rightly said respecting it that it is as obvious to the astronomer as the motion of the sun or moon to the ordinary observer Now, the evidence it supplies amounts in effect to this —Every star seems to sway isochronously with the sun's apparent yearly motion round the earth, stars on the ecliptic moving backwards and forwards along a straight line, other stars swaying round and round in an ellipse, and stars close by the pole of the ecliptic traversing a circular path A simple explanation of all these motions is given by the theory that the earth moves round the sun, but if the earth be supposed at rest, then all these motions remain unaccounted for It need hardly be said, then, that independently of the evidence we have respecting the enormous distances and dimensions of the stars, we are forced to accept the simple explanation afforded by the theory of the earth's motion, rather than the view that the sun sweeps in a wide orbit round the earth, while all the stars sway responsive to his motions

If further evidence were needed, it would be supplied by the apparent motions of the planets, and the fact established by Copernicus and Kepler, that, assuming the sun as the centre of motion, all those complicated apparent motions receive a simple interpretation

But by the modern astronomer the motions of the earth are not referred for proof even to such striking evidences as these, but to the enormous and ever increasing mass of evidence derived from the exact accordance of the minutest peculiarities of planetary motion with those which calculation shows should result from the law of universal gravitation

The Earth's Magnitude and Figure The general proofs that the earth is globe shaped are too well known to be insisted upon here at any length. The appearance of the horizon at sea, the fact that objects come into view or pass out of view beyond that horizon as beyond a convex hill, the shape of the earth's shadow in lunar eclipses, the elevation or depression of the pole of the heavens with northward or southward voyages, the fact that the earth can be circumnavi-

gated, and that it can be voyaged round (though not by sea) in a number of definite directions, —all these and a number of other evidences have long since proved to all save the most ignorant that the earth's form is globular The exact determination of the figure and magnitude of this globe constitutes one of the most striking triumphs of modern science The globe figure of the earth once recognised, it became possible to determine the diameter of that globe (assumed in the first place to be a true sphere) by measuring arcs either of an arc of latitude or longitude (See *Degree of Latitude*) So soon, however, as it was further ascertained that the earth rotates upon an axis, the idea was suggested that the figure of the earth cannot be a perfect sphere, but that the polar diameter must be less than a diameter of the earth's equator Adopting, for convenience, an inexact mode of treating the problem, Newton was led to the conclusion that the earth's polar and equatorial diameters bear to each other the ratio of 229 230 But it was seen that the actual compression of the earth must in a large part depend on the constitution of her internal strata Newton had assumed a fluid structure homogeneous throughout But the density of the earth increases towards the centre, as will presently be shown, and it results that a smaller compression corresponds to the conditions of equilibrium We owe to Maclaurin, Clairaut, and Ivory, the mathematical examination of the problem of the figure of equilibrium of a rotating fluid globe, and though it can scarcely be said that such a globe must necessarily assume the figure of a spheroid, yet it has at least been demonstrated that that figure is one of those under which such a globe would be in equilibrium, while it has been further shown that under such conditions as we may suppose to have probably existed in the case of our own earth, the figure of an oblate spheroid would necessarily result, and further that the compression of that spheroid would be about $\frac{1}{300}$

The actual measurements applied to the earth's surface are not absolutely independent of any preconceived theories So far as the mere determination of the earth's generally globular figure is concerned they are, of course, completely independent of theory But in those difficult geodetical operations by which the departure of the earth from the figure of a perfect sphere are not merely to be shown to exist, but actually to be estimated in quantity and measure, it is necessary to assume as the basis of research a general symmetry of figure, which may not in reality exist Yet the fact that these assumptions have been made, need by no means prevent us from accepting with full confidence the results of geodetic operations, for these operations are pursued with sufficient completeness to prove whether the initial assumptions are or are not reliable, and as a matter of fact, it has been discovered that the earth's figure is not perfectly symmetrical, even when we suppose all such irregularities as mountain-ranges, valleys, and so on, removed, and the figure we have to determine to be that which would result if these relatively small elevations and depressions were removed

It will be seen from what is said under *Degree of Latitude* and *Degree of Longitude* how the general ellipticity of the earth's figure can be recognised and measured It may be taken for granted that the compression of the earth is not far, either in excess or defect, from $\frac{1}{300}$ This result is confirmed by the observed extent of the motions called *Precession* and *Nutation* (*q v*)

But Captain A R Clark, R E, by combining all the results which have been obtained, and especially those resulting from the recent extension of the great arcs surveyed in India and Russia, has been led to conclusions (Memoirs of the Royal Astronomical Society, vol XXIX, 1860) which have been thus stated by Sir John Herschel —

"The earth is not exactly an ellipsoid of revolution The equator itself is slightly elliptic, the longer and shorter diameters being respectively 41,852,864 and 41,843,096 feet The ellipticity of the equatorial circumference is therefore $\frac{1}{4233}$, and the excess of its longer over its shorter diameter about two miles The vertices of the longer diameter are situated in longitudes 14° 23′ E and 194° 23′ E of Greenwich, and of its shorter in 104° 23′ E and 284° 23′ E The polar axis of the earth is 41,707,796 feet in length, and consequently the most elliptic meridian (that of longitude 14° 23′ and 194° 23′) has for its ellipticity $\frac{1}{287\cdot5}$, and the least so (that of longitude 104° 23′ and 284° 23′) an ellipticity of $\frac{1}{303\cdot8}$"

General Schubert, in the Memoirs of the Imperial Academy of Petersburg, exhibits a somewhat different mode of treatment (less exact, Sir J Herschel considers) leading to a similar but not altogether coincident result "He makes the ellipticity of the equator $\frac{1}{3865}$, and places the vertices of the longer axis 26° 41′ to the eastward of Captain Clark's His polar axis as deduced from each of the three great meridian arcs, the Russian, Indian, and French respectively, is 41,711,019 feet, 41,712,534 feet, and 41,697,496 feet, the mean of which, giving to each a weight proportional to the length of the arc from which it is deduced, is 41,708,710 feet."

Density of the Earth The number which expresses the ratio of the mass of the earth to that of the same bulk of water To determine the mean density of the earth is to find an answer to the question, Is the mass of the earth greater than it would be if composed throughout of water at the ordinary density, and if so, how many times greater? The ordinary data of astronomy, taken in conjunction with the laws of gravitation, give the proportions of the mass of the earth to the masses of the sun and the principal planets, and thus the determination of the absolute mass of the earth will at once give determinations of the absolute masses of the sun and planets, and then, as their dimensions are known, their densities can be found We may then determine, for instance, whether the planet Jupiter is composed of materials as light as water, or as light as cork

The obvious importance of these investigations induced philosophers long since to attempt determinations of the earth's density, and four classes of experiments have been devised for it The first kind of experiment depends on the attraction of a mountain, and has been tried in the noble Schehallien experiment, and later by Colonel James and others. It rests, in the first place, upon the use of the zenith sector, and, in the next place, upon our approximate knowledge of the dimensions of the earth

The zenith sector consists of a telescope with a graduated arc attached to the lower end, and a plumb line attached to the upper end (See *Zenith Sector*) If the same star were observed at two places, the telescope would necessarily be pointed in the same direction at the two places, and the difference of direction of the plumb-line, as shown by the different points of the graduated arc which it crossed at the two places, would show how much the direction of gravity at one place is inclined to the direction of gravity at the other place Now, from our knowledge of the form and dimensions of the earth, we know that the direction of gravity changes very nearly one second of angle for every 100 feet of horizontal distance. Suppose then, that two stations were taken on Schehallien, one on the north side and the other on the south side, and suppose that their distance was 4000 feet, then, if the direction of gravity had not been influenced by the mountain, the inclination of the plumb lines at these two places would have been about 40 seconds But suppose, on applying the zenith sector, in the way just described, the inclination was found to be really 52 seconds The difference, or 12 seconds, could only be explained by the attraction of the mountain, which, combined with what may be called the natural direction of gravity, produced directions inclined to these natural directions In order to infer from this the density of the earth, a calculation was made (founded upon a very accurate measure of the mountain) of what would have been the disturbing effect of the mountain if it had been as dense as the interior of the earth It was found that the disturbance was really only 12 seconds Consequently the proportion of the density of the mountain to that of the earth was as 12 to 27, or as 4 to 9 nearly From this, and the ascertained density of the mountain, it followed that the mean specific gravity of the earth would be about five times that of water The only objection to this admirable experiment is, that the form of country near the mountain is very irregular, and it is difficult to say how much of the 12 seconds is or is not really due to Schehallien

The effect of the attraction of a mountain on the direction of the plumb-line was observed in 1738 by Bouguer and other French academicians during experiments on Chimborazo in Peru More recently, Colonel James, superintendent of the Ordnance Survey, by observations made on Arthur's Seat, near Edinburgh, has deduced a mean density of 5 316.

Another mode of determining the earth's mass, is founded on the fact that a pendulum suspended at a considerable elevation above the earth will oscillate more slowly than one at the earth's surface, on account of the diminution of attraction with increase of distance from the centre of the earth Clearly, if the pendulum, instead of being simply raised above the earth, is placed at the summit of a mountain, the attraction of that mountain mass will appreciably affect the result, and if we know the mass of the mountain, we can deduce an estimate of the earth's mass From observations made on Mount Cenis, on this plan, Carlini and Plana have deduced 4 950 for the earth's mean density.

The converse of this plan is also obviously available as a means of estimating the earth's density Professor Airy, in 1826, first contemplated the solution of the problem by the determination of the difference of gravity at the top and the bottom of a deep mine, by pendulum experiments Supposing the difference of gravity found, its application to the determination of density may be thus explained. Conceive a spheroid concentric with the external spheroid of the earth to pass through the lower station in the mine It is easily shown that the attraction of the shell included between these produces no effect whatever at the lower station, but produces the same effect at the upper station as if all its matter were collected at the earth's centre (See *Attraction*) Therefore, at the lower station we have the attraction of the interior mass only, at the upper station we have the attraction of the interior mass (though at a greater distance from the attracted pendulum), and also the attraction of the shell. It is plain that by making the proportion of these theoretical attractions equal to the

proportion actually observed by means of the pendulum, we have the requisite elements for finding the proportion of the shell's attraction to the internal mass's attraction, and, therefore, the proportion of the matter in the shell to the matter in the internal mass. From these data the mean density is at once found. It will, of course, be understood, however, that the actual solution of the problem is complicated by the fact that the extent of the mine itself, as well as the nature of the strata through which it is formed, have to be considered.

Having tried the experiment in 1826 and in 1828, and failed through accident, the Astronomer Royal renewed the attempt in 1854 at the Harton colliery, near South Shields, where a reputed depth of 1260 feet could be obtained.

The two stations selected were exactly in the same vertical, excellently walled, floored, and ceiled. Every care was taken to secure solidity of foundation and steadiness of temperature. In each station (the upper and lower) was mounted an invariable brass pendulum, vibrating by means of a steel knife-edge upon plates of agate, carried by a very firm iron stand. Close behind it was a clock, and before it a telescope mounted so that coincidences of the pendulum of the clock might be accurately observed through a slit in front of the telescope. By this means the proportion of invariable-pendulum swings to clock pendulum swings was found, and then as the clock-pendulum-swings, in any required time, are denoted by the clock dial, the corresponding numbers of invariable-pendulum-swings at the two stations were determined. In order, however, to do this, the clock rates had to be frequently compared, this was done by means of electrical apparatus.

In this manner the pendulums were observed, with 104 hours of incessant observations, simultaneous at both stations, one pendulum (A) being above and the other (B) below, then with 104 hours, B above and A below, then with 60 hours, A above, and B below, then with 60 hours, B above, and A below. 2454 effective signals were observed at each station.

The result showed that the pendulums suffered no injury in their changes, and that the acceleration of the pendulum, on being carried down 1260 feet, was $2\frac{1}{4}$ seconds per day, or that gravity is increased by $\frac{1}{19190}$ part. It does not appear likely that this determination can be sensibly in error. Hence Mr Airy calculated that taking into account, as far as possible, the configuration of the mine, and the structure of the neighbouring region, the earth's density is 6.565. He adds that he considers this result to be comparable on at least equal terms with those obtained by other methods, an opinion which seems more than questionable, when the complexity of the considerations to be attended to in the mine method is fairly taken into account.

The last method we shall refer to, is that applied in the well known Cavendish experiment. The method was suggested by Michel, and, since the experiments of Cavendish, it has been applied by Reich of Freyberg, and by the late Francis Baily. It involves, in principle, the direct comparison between the earth's attraction, and that exerted by a mass of known weight. Two large globes of lead are placed upon the extremities of a strong horizontal rod, which can be turned in a horizontal plane about its centre. A cord supports, above that centre, a fine horizontal rod, at whose extremities are two equal balls, about 2 inches in diameter. When this rod is as nearly in perfect equilibrium as possible (true equilibrium is seldom secured), the frame bearing the globes of lead is rotated on its vertical axis until they are brought nearly into contact with the small balls, on opposite sides. Their attraction on these balls thus tends to sway the fine rod from its position of rest. By turning the frame round in an opposite direction, until the large balls are again nearly in contact with the small ones, the fine rod is swayed in a contrary direction from its position of rest. By observations made on the extent of these deviations, taking the average of many experiments (Baily made more than 2000), it is possible to compare the attractive force of the lead balls with that of the earth. Of course the precautions necessary to insure success in an observation of so much delicacy, are very numerous, and difficulties depending on the torsion of the suspending cord, on air currents resulting from differences of temperature, and so on, interfere to prevent the solution of the problem from being rigorously accurate. Still it may fairly be asserted that more reliance can be placed on this method of determining the earth's mass than on any other. The results obtained by the three observers, named above, accord in a very satisfactory manner. The experiments of Cavendish gave for the earth's mean density 5.480, those of Reich 5.438, and those of Francis Baily 5.660. The mean of all the results obtained by this and other methods is 5.639.

We may thus fairly assume that the earth's mean density is not very far from 5.6 times the density of water. By combining this result with what has been already mentioned respecting the dimensions of the earth, we find that the weight of the earth in tons is roundly expressed by the number 6,000,000,000,000,000,000,000. As the average density of the parts of the earth's crust known to us is considerably less than 5.6, it follows, as was indeed to have been expected, that the density increases with approach towards the centre.

Temperature of the Earth. Although we have at present no means of determining the mean temperature of the earth, still less the actual temperature of different parts of the earth's substance at considerable depths, we have many reasons for believing that the earth's interior

is at a much higher temperature than the portions of the crust to which we are able to penetrate Passing below those levels at which the effects of the sun's heat are experienced, either in diurnal or annual variations of temperature, we find a gradual increase of temperature as we descend The rate of increase has been estimated at nearly 100° per mile of vertical descent, so that supposing it to continue through a distance of but 100 miles (that is but a 35th part of the earth's radius), a temperature of no less than 10,000° Fahrenheit must exist at that depth below us Such a temperature would liquify all solid substances with which we are acquainted, and vaporise many solid elements As the increase of temperature has always been found, wherever subterranean excavations have been made, we must, at least until clear evidence to the contrary is adduced, suppose it to be a characteristic of all parts of the earth's crust, so that we seem to have no escape from the conclusion that the whole interior of the earth is molten It has been estimated, indeed, by M Cordier, that the solid crust of the earth cannot greatly exceed 60 miles in thickness Yet the researches of Mr Hopkins of Cambridge, into the phenomena of *Precession* (*q v*) show that the earth cannot really be constituted in the manner surmised by Cordier It may be questioned whether the effect of the enormous pressure to which the interior parts of the earth must be subjected, both from the weight of the superincumbent portion, and from the action of the imprisoned vapour of many of the terrestrial elements (assuming always that the enormous heat we have referred to really exists in the interior of the earth), must not suffice to remove the limits of the solid crust far below M Cordier's estimate Perhaps several hundred miles below the surface of the earth liquefaction may begin, though far below even that depth there may still remain sufficient viscosity to prevent those free movements of the liquid nucleus which Mr Hopkins has dealt with

But the whole subject is too far removed from the range of observational science to admit of being dealt with satisfactorily We can only speculate as yet on the condition of the earth's interior, nor is it likely that the time is as yet near at hand when we shall be able to do more

The view put forward by Poisson that the heat observed in the earth's crust has been stored up while the solar system was passing in long past ages through a warm region of space, seems too speculative to merit very attentive consideration Yet it is not wholly impossible that when we know more respecting the sun's motion through space on the one hand, and respecting the mode in which the supplies of solar heat are obtained on the other, we may recognise in the peculiarities of the regions through which the sun has borne and is bearing his family of planets, the interpretation of many problems of interest suggested by the present condition of the earth's temperature, and the traces of past changes in this respect

EARTH CURRENTS Telegraphic lines of considerable length are much disturbed by what are called *earth currents* Strong irregular currents are observed to flow from one part of the line to another, affecting the instruments of course, and frequently rendering telegraphic communication for the time impossible But little is known of the laws of earth currents, apparently they depend upon alterations, in the state of the earth's electrification which produce currents in the wires by induction They occur simultaneously with magnetic storms and auroræ Dr Balfour Stewart ascribes earth currents and auroræ to secondary discharges taking place in consequence of variations in terrestrial magnetism

EARTH SHINE A name given by astronomers to that faint light visible on the part of the moon not illuminated by the sun, either soon before or soon after new moon It may be assumed as certain that this light is due to the illumination of that part of the moon by the light which the earth reflects to her It must be remembered that at the time of new moon the earth shines in the lunar skies with a disc about 13 times as large as the disc of the moon on our own skies

EBONITE See *Caoutchouc*

EBULLITION (*Ebullio*, to boil, or bubble up) We have mentioned, under the head of *Vaporisation*, that there are two principal modes according to which a liquid assumes the gaseous condition—the first of these is *evaporation*, the second *ebullition* When a liquid is heated it continues to acquire heat, until at a certain point vapour is formed within its mass, and the temperature no longer rises The liquid is now in a state of violent perturbation, and is giving off bubbles of vapour from the hottest portion of the interior of its mass, it is, in fact, in a state of *ebullition*, or, as we more commonly say, it *boils* The temperature at which ebullition takes place depends on various causes, the principal of which are the nature of the liquid, and the external pressure, substances dissolved in the liquid also affect its boiling point, and to a slight extent the nature of the containing vessel

A glance at the table, given under the head of *Boiling Point*, will show the great variations in the temperatures at which different liquids enter into ebullition, and we can quite understand that this must be the case when we remember that, with a difference of composition in a substance, we necessarily have a difference in the structure, weight, and cohesive force of its molecules, whence they assume the gaseous condition under very varied circumstances of temperature.

As regards the effect of external pressure, an increase of pressure raises the boiling point, and a diminution of pressure diminishes it, because in the one instance there is a larger amount of external work to be overcome than in the other. The influence of pressure is most marked; certain volatile liquids—ether for example—which do not boil at ordinary temperatures in the air, boil readily in an exhausted receiver. Again if we heat water to the boiling point, and allow it to cool considerably, the boiling is instantly recommenced when it is placed under the receiver of an air-pump, on exhausting the air. Since, therefore, a diminution of atmospheric pressure leads to a lowering of the temperature at which liquids enter into ebullition, we can well understand that the boiling points of liquids vary with the elevation above the sea level; hence the height of a place above the sea level should always be stated side by side with the boiling point, when the locality possesses any considerable elevation. At the summit of Mont Blanc water boils at 185° F., that is to say, the boiling point is lowered 27° F. We can thus quite account for the statements of travellers, that in very elevated regions they have found it impossible to boil potatoes. The height of a mountain may be roughly determined by noticing the boiling point of water at its summit, for by this means the pressure of the air is shown, and the pressure corresponding to a given height is known. The boiling point of water has been found to be lowered about 1° F. for every 590 feet of elevation.

Pouillet gives the following table of the boiling points of water at various places situated at different heights above the level of the sea:—

Names of Places	Height above the level of the sea	Mean height of the Barometer	Boiling point of water
	Feet	*Inches*	*Degrees Fah*
Farm of Antisana,	13,455	17.87	187.4
Town of Micuipampa (Peru),	11,670	19.02	190.2
Quito,	9,541	20.75	191.2
Town of Caxamarca (Peru),	9,304	20.91	194.5
Santa Fé de Bogota,	8,731	21.42	195.6
Cuenca (Quito),	8,639	21.50	195.8
Mexico,	7,471	22.52	198.1
Hospice of St Gothard,	6,808	23.07	199.2
St Veron (Maritime Alps),	6,693	23.15	199.4
Breuil (Valley of Mont Cervin),	6,585	23.27	199.6
Maurin (Lower Alps),	6,240	23.58	200.3
St Remi,	5,265	24.45	202.1
Heas (Pyrenees),	4,807	24.88	202.8
Gavarnie (Pyrenees),	4,738	24.96	203.0
Briançon	4,285	25.39	203.9
Barège (Pyrenees),	4,104	25.51	204.1
Palace of St Ildefonso (Spain),	3,790	25.87	204.8
Baths of Mont d'Or (Auvergne),	3,412	26.26	205.7
Pontarlier,	2,717	26.97	206.8
Madrid,	1,995	27.72	208.0
Innsbruck,	1,857	27.87	208.4
Munich,	1,765	27.95	208.6
Lausanne,	1,663	28.08	208.9
Augsburg,	1,558	28.19	209.1
Salzburg,	1,483	28.27	209.1
Neufchatel,	1,437	28.31	209.3
Plombières,	1,381	28.39	209.3
Clermont Ferrand (Préfecture),	1,348	28.43	209.3
Geneva and Friburg,	1,221	28.54	209.5
Ulm,	1,211	28.58	209.7
Ratisbon,	1,188	28.58	209.7
Moscow,	984	28.82	210.2
Gotha,	935	28.86	210.2
Turin,	755	29.06	210.4
Dijon,	712	29.14	210.6
Prague,	587	29.25	210.7
Mâcon (Saône),	551	29.29	210.9
Lyons (Rhone),	532	29.33	210.9
Cassel,	518	29.33	210.9
Gottingen,	440	29.41	211.1
Vienna (Danube),	436	29.41	211.1
Milan (Botanic Garden),	420	29.45	211.1
Bologna,	397	29.49	211.1
Parma,	305	29.57	211.3
Dresden,	295	29.61	211.3
Paris (Royal Observatory, first floor)	213	29.69	211.5
Rome (Capitol),	151	29.76	211.6
Berlin,	131	29.76	211.6
Level of the sea,	0	30.00	212.0

When a substance is simply suspended in, or mixed with, a liquid, upon which it has no action, the boiling point of the liquid is not altered, thus, if saw-dust or sand is mixed with water the boiling point remains 212° F But if the substance is actually dissolved in the liquid the boiling point is altered, thus a solution of brine has a higher boiling point than water, and a solution of resin in alcohol, than alcohol, but if we mix alcohol (boiling point = 173 1° F) with water, we have a mixture which possesses a higher boiling point than alcohol, and a lower boiling point than water A saturated solution of common salt boils at 227 12° F, and a saturated solution of chloride of calcium at 355 1° F

The air which is dissolved in liquids tends to lower their boiling point When water has been freed from air as completely as possible by long continued boiling, it may be raised to a temperature far above the boiling point, without entering into ebullition M Donny of Ghent has raised water thus freed from air to a temperature of 135° C (275° F) without ebullition, but above this temperature the heated water was jerked violently from one end of the tube containing it, to the other, and sometimes an explosion took place with extreme violence Mr Grove found that water might be boiled to dryness, and yet permanent gas was given off continuously "I believe," he writes, "that no one has seen the phenomenon of pure boiling without permanent gas being freed"

Water boils at a higher temperature in a glass than in a metal vessel, the boiling point may be raised to 102° C in a glass vessel, and if the latter be lined inside with resin, the water may attain a temperature of 105° C

According to Mr Tomlinson (Proc Royal Society, 1869) a liquid at or near the boiling point is a supersaturated solution of its own vapour

Nuclei (see *Nucleus*) act on such a solution under similar conditions to those of supersaturated saline solutions (see *Supersaturation*), the nuclear body having a stronger attraction for the vapour, than for the liquid of the solution

Such a solution adheres to a catharised or chemically clean body (see *Catharism*) as a whole, and hence there is no separation of vapour from such surfaces

The action of such a solution is to convert nuclei in or nuclear into catharised or non nuclear surfaces, when the solution adhering to them as a whole, more vapour passes into solution, and the temperature rises until the elastic force of the dissolved vapour, overcoming the adhesive force of the liquid, a portion escapes in a burst, with a sort of dull explosion This produces an immediate depression in temperature, but the steam again accumulating, produces a rise in temperature, and then another burst, and so on

This bursting ebullition occasions a jumping of the vessel, or *soubresaut*, as it is called in French science This is occasioned by the burst of steam escaping along the line of least resistance, or by the mouth of the vessel, and producing a corresponding reaction or pressure in a downward direction upon the support of the vessel It is the rebound from this that occasions the rising or jumping of the vessel

If a vessel containing water and a little sand, all chemically clean, be suspended by a piece of elastic, or by a weak spring, and be boiled, the motions of the vessel can be readily traced

In the distillation of many liquids, especially vinous and ethereal ones, their action is to catharise the interior walls of the retort or other vessel, and thus produce dangerous *soubresauts* Bits of metal, fragments of glass, sand, &c, put into the vessel as "promoters of vaporisation," prevent or mitigate the bumping for a short time, but they soon become chemically clean, and then aggravate the evil they were intended to prevent by enlarging the adhesion surfaces instead of the vapour-giving surfaces

It was commonly supposed that rough or angular bodies were peculiarly active in liberating vapour, but Mr Tomlinson has shown that such bodies, if chemically clean, are quite inactive as nuclei Rough bodies, however, store up nuclear matter in their furrows, and they are not so readily catharised as smooth surfaces

There is, however, one set of bodies that has the property of liberating vapour from solution, and does not lose it by use or by being catharised Such are porous bodies, the best of which is charcoal, and the best charcoal is that made from cocoa nut shell

Cocoa-nut shell charcoal, on account of its superior density, occupies the bottom of the vessel, containing liquids somewhat heavier than water, and when heat is applied, the charcoal kicks or jumps instead of the vessel, while at the boiling point the charcoal pours out unceasing floods of vapour, lowering the boiling point, and increasing the quantity of the distillate with the same amount of heat

Mr Tomlinson has drawn this conclusion from a number of comparative experiments, in which the amount of liquid boiled or distilled without the assistance of a nucleus, is compared with the amount obtained with a nucleus Thus water lost in boiling, during twenty minutes, 995 grains, but when a few bits of coke were added it lost 1130 grains in the same time

This gives ratio of products 100 113 6

In another case where charcoal was the nucleus, the ratio of results was 100 127 4

Methylated spirits of wine boiling at 171° F was distilled, the distillate in five minutes weighing 244 grains With 20 grains of charcoal the distillate in five minutes weighed 325 grains, or as 100 133 2

Instead of charcoal 20 grains of pumice were put in the retort The ratio was then as 100 121 7

With 20 grains of meerschaum as 100 112

With 20 grains of coke, as 100 107 46

Porous bodies, such as charcoal, pumice, meerschaum, and even a bundle of capillary glass tubes, act either on Saussure's principle of the absorption of gases by porous bodies, or by affording spaces for the pent-up steam to expand into and so escape

ECCENTRIC In astronomy, a term belonging to the the *Ptolemaic System* (*q v*)

ECCENTRIC In mechanics, a wheel revolving about an axis which is not its centre of figure, so as to produce the alternate action of the valves of a steam engine

Let us suppose C to be the centre of a metallic circular plate, and let the plate be pierced at G, a point between C and the circumference, for the reception of the revolving shaft Let the circular plate be fixed to the shaft so as to turn with it The centre C of the plate will describe a circle round the centre G of the shaft, the radius of which will be the distance C G The disc and shaft form an eccentric A metallic ring or collar fits the circular plate so that the latter can turn in the former An arm divided at one end into two prongs is attached to the sides of the ring While the eccentric revolves, since the ring does not partake of its revolution the arm will be alternately driven to the right and left in the revolution Suppose the arm to be on the right of the shaft, then when the centre C of the disc and the centre G of the shaft are in the same line with the direction of the arm and C on the right of G, then the arm has its limiting position on the right, but when half a revolution of the main axle has been made, C will be on the left of G, and the arm will then have its limiting position on the left The length through which the arm moves is termed the *throw* of the eccentric, the throw is therefore equal to twice the distance between the centres of the disc and shaft By means of an arrangement of levers the arm moves the slide valve of the engine, and it is evident that by a suitable adjustment of the eccentric upon the shaft, the valves may be opened and closed at any required position of the piston in the cylinder

ECCENTRICITY OF AN ORBIT (ἐκ, out of, and κέντρον, a centre) The absolute eccentricity of an orbit is the distance between the centre of an elliptic orbit and either focus But, what is always understood by astronomers as the eccentricity of an orbit, is the ratio which the above distance bears to the mean distance, or semi-major axis Thus if the eccentricity of an orbit is said to be 0 01, what is meant is that the centre of the orbit is at a distance from either focus, equal to $\frac{1}{100}$th part of the semi major axis of the orbit

ECHO See *Reflection of Sound*

ECLIPSE (ἐκλείπω, to fade away, to vanish) The obscuration of one celestial body by another, whether by the direct interception of the light coming from the former, or by the interception of the light by which the former is illuminated Eclipses of the former kind include occultations of stars and planets by the moon, transits of the satellites of Jupiter and Saturn over the disc of their primaries, the occultations of these satellites by their primaries, and transits of Venus and Mercury over the face of the sun But, commonly, astronomers restrict the term eclipse to events of the following classes —

(1) The obscuration of the sun by the moon, which is called a *solar eclipse*

(2) The obscuration of the moon by the shadow of the earth, which is called a lunar eclipse

(3) The obscuration of a satellite of a planet by the *shadow* of the primary, which is called an *eclipse of a satellite*, as distinguished from an occultation of the satellite by the *disc* of its primary

A few remarks must be made on the general subject of solar and lunar eclipses before we proceed to consider them separately

Since the moon circles round the earth in a path inclined rather more than 5° to the plane of the ecliptic, it is clear that an eclipse can only take place when the moon, at the time of "new" or "full," is near one of the points where she crosses the ecliptic—in other words, near one of her nodes At this time, then, the moon's line of nodes must be directed nearly towards the sun Now, considering successive conjunctions of the three bodies,—the earth, sun, and moon,—on nearly the same line, and regarding the moon's orbit, for the moment, as moving parallel to itself, precisely as the earth's equator does, it will be evident that as these conjunctions take place at intervals of about a fortnight along radial lines from the sun, which advance with the earth's motion, there are only two seasons of the year at

which they take place when the line of the moon's nodes passes nearly through the sun (precisely as the sun is only twice a year upon the plane of the earth's equator) And all that is necessary to make this view of the case correspond with the actual facts, is to remember that the moon's line of nodes has not a fixed direction on the ecliptic, but sometimes progressing, at others retrograding, on the whole is carried retrogressively round the ecliptic once in somewhat less than 19 years, so that it passes, in reality, 40 times through the sun in that time, instead of only 38

Hence about 40 times in 19 years the moon's orbit is favourably situated for the occurrence of an eclipse One of these epochs cannot pass without one eclipse at least, frequently there occur two, and sometimes there occur three Thus there must always be two eclipses, at least, in every year, and there may be more The absolute maximum is seven, corresponding to the case in which three eclipses occur at each of two eclipse seasons (to coin a convenient word) and an eclipse belonging to a third season just falls within the year—the possibility of which will be seen when it is remembered that the interval separating these eclipse seasons is somewhat less than half a year

But now let us consider how it happens that there must be one, and may be three, eclipses at each of the eclipse-seasons

Suppose the line of nodes passed through the sun when the moon was one quarter full Then, both at the preceding and at the following conjunctions (using this term for convenience to include both new and full moon), the line of nodes lies still too near to the sun for an eclipse to be avoided Hence in this case there must be two eclipses, and as this is the most favourable case for the absolute avoidance of eclipse, and, as this case fails, we see that, in no case, can an eclipse be absolutely avoided But suppose that the line of nodes passes through the sun at the time of new moon Then there is, of course, an eclipse of the sun, (a central one) Now the interval of time separating this conjunction from the preceding and following full moons is about twice as great as the intervals which, in the last case, separated the times of conjunction from the passage of the line of nodes through the sun's centre Hence the distance of the moon from her nodes is so much greater, at both these epochs, that no part of her globe falls within the earth's shadow, and, therefore, there is no lunar eclipse Thus there occurs but one eclipse at this eclipse season, and that eclipse is a central solar one But it is worth noticing that, in this instance, the moon, at both the epochs considered, passes through the penumbra of the earth, and that, though the Nautical Almanac takes no note of it, there is always one penumbral lunar eclipse, at least, whenever a solar eclipse occurs, which is neither preceded nor followed by an ordinary lunar eclipse at the preceding and following occurrence of full moon Thirdly, if the line of nodes passes through the sun at the time of full moon, there is a total lunar eclipse At the preceding and following conjunctions of the sun and moon, the moon would, in this case, be considerably removed from her node, but not so far but that she would partially eclipse the sun Thus, in this case, there would be three eclipses, one lunar and central, the others occurring one about a fortnight before, and the other about a fortnight after, and both of them solar and partial

It will easily be seen that in intermediate cases, one or other of the three results here considered must take place There can never be more than three eclipses, nor less than one, if there are three, two are solar and partial, if there is but one, it is solar and central Where there are two, one must be solar, the other lunar, and either, but not both, may be total

It follows that, on the whole, solar eclipses must be more numerous than lunar ones, since, whenever a single eclipse occurs at the eclipse season, it is a solar one, and, whenever three occur, two out of the three are solar It has been calculated that for every 21,600 lunations, there are 4,072 solar and 2,614 lunar eclipses The general reason for this numerical superiority of solar eclipses is easily recognised in the fact, that if a cone be conceived to enclose both the earth and sun, its vertex lying without the earth, a solar eclipse will occur whenever the moon, in passing between the earth and sun, comes wholly, or in part, within this cone, while for a lunar eclipse the moon must also pass wholly, or in part, within this cone, but outside the earth's orbit, or where the cone is smaller (See *Ecliptic Limits*)

On the contrary, if penumbral lunar eclipses (which theoretically correspond with partial solar ones) be included, lunar eclipses will be the more frequent, since then a lunar eclipse will occur whenever the moon (beyond the earth's orbit) passes wholly or in part within the cone enclosing both the earth and sun, but having its vertex between these bodies, and it is easily seen that the section of this cone at the moon's distance beyond the earth's orbit is greater than the section of the former cone at the moon's distance within the earth's orbit

It is to be added that, at any given station on the earth, lunar eclipses are more often seen than solar ones, the reason being that a lunar eclipse is visible from all stations at which the moon is visible, whereas an eclipse of the sun is only visible from a limited portion of the earth's surface.

We proceed to consider the special characteristics of solar and lunar eclipses

Solar Eclipse A solar eclipse may be total, annular, or partial In a *total eclipse*, the whole disc of the sun is concealed by the moon, in an *annular eclipse*, the whole disc of the moon is projected within the sun's, in a partial eclipse, the moon's disc overlaps the sun's, the outlines of the two discs being, in this case, intersecting circles

We may consider solar eclipses in two ways If we conceive the motions of the solar and lunar discs, and remember within what limits these discs vary in size, we shall see that the various orders of solar eclipse are fully accounted for The limits between which the apparent diameter of the sun varies are 32′ 36 4″ and 31′ 31 8″, while the lunar disc varies in apparent diameter from 33′ 31 1″ to 29′ 21 9″ Thus central solar eclipses may vary between the case when the sun's disc has its greatest and the moon's its least diameter, in which case a ring of light will remain whose breadth will be

$$\tfrac{1}{2}\,(32'\ 36\ 4''—29'\ 21\ 9''),\ \text{or}\ 1'\ 37\ 2'',$$

and the case when the sun's disc has its least and the moon its greatest diameter, in which case the moon's disc will extend beyond the sun's by a breadth of

$$\tfrac{1}{2}\,(33'\ 31\ 1''—31'\ 31\ 8''),\ \text{or}\ 5\ 96''$$

Or, instead of adopting this mode of viewing the subject, we may consider the nature of the cone as enclosing both the sun and moon, and having its vertex beyond the moon The part of this cone which lies beyond the moon is the moon's shadow If, at the time of new moon, any part of this shadow falls on the earth, the sun is totally eclipsed as respects all those places which are thus in shadow On the contrary, it is easily seen that if the shadow does *not* reach the earth, but the production of the cone beyond its vertex *does*, then to all parts of the earth on which this produced part of the cone falls an annular eclipse is visible If neither the cone nor its production beyond the vertex touches the earth, but a cone enveloping both the moon and sun, and having its vertex between those bodies, reaches the earth, then, at any part of the earth falling within *this* cone, the sun appears partially eclipsed

Lunar Eclipses For the occurrence of a lunar eclipse, all that is necessary is that the moon should pass within the cone enveloping the sun and earth, and having its vertex outside the earth The diameter of the cross section of this shadow cone, where the moon's orbit passes across it, must, however, be supposed to be increased by about 1-60th part, on account of the earth's atmosphere The diameter of the reduced section exceeds the moon's on the average about three times

For the phenomena presented during solar eclipses see *Corona, Prominences*, &c During lunar eclipses few phenomena of importance have hitherto been noticed The most remarkable, perhaps, is the red and almost fiery colour sometimes presented by the moon when totally eclipsed Sometimes, however, the moon has been wholly invisible at such times

For eclipses of Jupiter's satellites see *Jupiter*

ECLIPTIC (ἐκ, and λείπω, to pass away from) The great circle of the heavens along which the sun's centre appears to move in the course of a year Its name is derived from the circumstance that eclipses, either of the moon or of the sun, can only happen when the former body is on or near the ecliptic The ecliptic is inclined about 23½ degrees to the equator (See *Obliquity of the Ecliptic*) It is divided by astronomers into 12 portions, each of 30 degrees These are called signs, and serve conveniently to indicate the course of the sun along the circle The point where he passes from the southern to the northern side of the equator is called the first point of Aries, and the sign Aries extends 30 degrees from this point Then follow the signs in the order—Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricornus, Aquarius, Pisces The sun's motion along the ecliptic is not uniform, so that he continues a longer time in some signs than in others He moves most slowly along the ecliptic in summer (Compare *Aries, Taurus*, &c, under which heads the approximate dates on which the sun enters and leaves each sign will be found specified) Owing to the precession of the equinoxes, the signs no longer agree with the constellations which bear the same name, the sign Aries falling on the constellation Pisces, and so on

ECLIPTIC LIMITS The limits on either side of the lunar nodes, within which the moon must be when new or full, in order that a solar or lunar eclipse may take place For a solar eclipse the limits have an average value of 16° 50′, for lunar eclipses they have an average value of 10° 53′

EFFUSION OF GASES. The escape of gases through minute apertures into a vacuum In his experiments to determine the rate of effusion of gases, Graham used thin sheets of metal or glass, perforated with minute apertures 086 millimetres or 003 of an inch in diameter The rates of effusion coincided so nearly with the rates of diffusion as to lead to the conclusion that both phenomena follow the same law, and, therefore, the rates of effusion are inversely as the square roots of the densities of the gases. (See *Diffusion*.)

ELASTIC FORCE OF VAPOUR The elastic force of the aqueous vapour in the atmosphere is an important element of meteorological inquiry It is, in reality, that portion of the barometric pressure which is due to the aqueous vapour in the atmosphere, and may be regarded as proportional to the absolute humidity of the air

ELASTICITY (*Elasticus*, from ἐλαύνειν, to drive) The property of certain bodies by which, after having been compressed or extended, they recover their former figure and dimension on the removal of the compressing or stretching force The most elastic bodies are gases, and there seems to be no limit to their elasticity If a quantity of gas be included in a syringe under a piston and be compressed by a force applied to the piston, on the removal of the force the gas will regain its former volume, forcing up the piston until it have recovered the position from which it had been driven by the compressing force Again, when the receiver of an air-pump is partially exhausted the air left in it entirely fills it

When liquids are compressed they immediately recover their original dimensions when relieved from the pressure, but the limits of compressibility and elasticity in liquids are so narrow that for all practical purposes liquids are treated as incompressible and inelastic Solid bodies differ very considerably in their elasticity If a flat surface of steel be smeared with a colouring matter, and an ivory ball be allowed to drop upon it, the ball will rebound On examining the part of the surface which struck the steel it will be found that a large circular mark has been made, showing that the surface has been flattened, but has recovered its figure by virtue of the elasticity of the ball Elasticity of impact is measured by a coefficient of elasticity which is constant for the same substances When an elastic bar or string is stretched by a force it is found by experiment that the extension varies as the product of the original length and the stretching force If the stretching force be multiplied by the original length and divided by the increase of length, the quotient is a constant quantity termed the modulus of elasticity This is termed, from the name of its discoverer, Hooke's law The modulus of elasticity for any uniform bar or string is the strain which would stretch it to double its natural length The following table of moduli is based on Professor Rankine's, (Applied Mechanics, p 631)

Material	Modulus	Material	Modulus
Wrought Iron bars,	29,000,000	Copper wire, . . .	17,000,000
Cast Iron, . . .	17,000,000	Oak, . . .	1,450,000
Brass, ...	8,900,000	Larch, . . .	1,050,000
Steel, ...	29,000,000	Fir, ...	1,330,000

ELASTICITY, OR TENSION, OF GASES All gases are, as far as is known, possessed of perfect elasticity, that is to say, if the pressure which has compressed them be withdrawn they will resume exactly their original volume If we regard a cylindrical tube, open at both ends, the air will press upon both the inside and outside of the substance and thus pinch it If one end of the cylinder be closed, it will be squeezed by the same force which the air, like all fluids, transmits equally in all directions Let us suppose now that there is in the cylinder a piston without weight It is at rest Pressed downwards as before by the weight of the air above it, it is no longer pressed upwards by the direct pressure of the air (this pressure is shut off by the closed bottom of the cylinder), but it is pressed up by the elastic force or tension of the air beneath the cylinder, which had been compressed before the piston was introduced The existence of both these pressures is easily shown by means of the air pump Thus, let a sheet of caoutchouc be stretched across one end of a cylinder, the other end being ground flat upon and covering the orifice of the air pump plate When the air is drawn out of the cylinder the elastic force or tension is withdrawn with it Consequently the pressure of the air on the top of the caoutchouc, meeting with no resistance from below, bulges the membrane inwards If, on the other hand, the mouth of a flask be covered with caoutchouc, and the whole be put under the receiver of the air pump from which the air is withdrawn, the membrane will be forced outwards, because the elastic force of the air in the flask (due to its previous compression) will no longer encounter the atmospheric pressure which is withdrawn Similarly a wet bladder, partially filled with air, will become fully distended when the pressure of the surrounding air is removed under the receiver of the air pump

ELECTIVE ABSORPTION OF LIGHT (*Electus*, selected) In optics the term used to express the absorption of the rays constituting light of a certain colour, in preference to those constituting light of other colours (See also *Colour, Absorption of*)

ELECTRICAL FISH Certain fish which have the power on being touched of giving an electric shock, similar to that given by a Leyden jar They have long been known, as is shown in a memoir by Professor Wilson, "On the Electric Fishes, as the Earliest Machines employed by Mankind"—Edinburgh Philosophical Journal, 1857 Of late they have engaged the attention of many investigators, among whom may be mentioned John Hunter, Galvani, Becquerel,

Breschet, Humboldt, Matteucci, Faraday The most celebrated species are the *Gymnotus Electricus*, or Electric Eel, and the *Raia Torpedo*

The former is found in South America in the streams which flow into the Orinoco, and it was there that Humboldt studied its nature It is a fish much like an eel, but with a more rounded obtuse nose than ordinary Its length varies from three to six feet A specimen which Faraday examined was 40 inches long On touching simultaneously two points in the body of the fish a powerful shock is experienced Faraday calculated that an ordinary discharge is equivalent to that of fifteen Leyden jars, having each 25 square feet of tinfoil coating Humboldt describes the taking of wild horses in South America by the aid of the Gymnotus The natives drive the animals in a body into a pond in which the fish abound, and the horses soon yield to the attacks, many of them being stunned, and some even killed The shock becomes gradually weaker on frequent repetition, the fish itself becomes exhausted, and after a time loses vitality The discharge has power to produce momentary currents in the galvanometer, to give a spark, or to effect chemical decomposition The organ by which the shock is produced appears to be a species of pile running from near to the head to the tail, and are supplied with some hundreds of pairs of nerves

The Torpedo has been carefully studied by Matteucci. It is a large fish, weighing often 80 lbs much like a skate It is found in the Bay of Biscay and in the Mediterranean Its electrical properties are similar to those which have been described in the case of the Gymnotus The shock is produced by a double organ situated in the two sides of the head, and uniting in front of the nasal bones Each of the parts is composed of a number of hexagonal prisms, presenting the appearance of a honeycomb, and four nerves go to each cell The prisms are filled with a liquid which consists of nine parts of water, one of albumen, and some chloride of sodium

Besides the Gymnotus and Torpedo there are some less powerful electric fish, the *Malapterurus Electricus*, which is found in the Nile, which is described by Professor Goodsir, the *Malapterurus Beninensis*, described by Mr Murray, Edinburgh Philosophical Journal, 1855, the *Silurus*, and others

ELECTRIC BATTERY See *Battery, Electric*

ELECTRIC BRUSH AND GLOW, SPECTRUM OF THE Schimkow has examined the spectrum of the electrical brush and glow (Poggendorff *Annalen*, CXXIX, pp 508–520) When the spectrum of the spark is affected by, and produced in both nitrogen and oxygen, the *brush* discharge only gives *nitrogen* lines, and is not formed at all in pure oxygen, a trace of nitrogen entering the tube is sufficient to reproduce the light and its peculiar lines The same is true in regard to the luminous glow observed when electricity is discharged between two points, but the latter spectrum is much fainter than that of the brush It is characteristic of these lines that they occur in the most refrangible part of the spectrum This seems due to the *much lower temperature* in the brush and glow discharge, as compared with the spark discharge By introducing into the circuit of a coil a wet string four metres long, Schimkow made the nitrogen spectrum of a Geissler tube appear precisely like the brush spectrum the yellow lines had been weakened much more than the violet ones, at a low temperature, therefore, nitrogen seems specially to emit the most refrangible rays, which agrees with the observations of Von Waltenhofen, according to which the least refrangible rays are first extinguished when air is successively more and more rarified Thus the *brush* and *glow* are due to the luminosity of nitrogen at a temperature below that at which oxygen becomes luminous, and furthermore they consist principally of the more refrangible rays

ELECTRIC CLOCK See *Clock, Electric*

ELECTRIC CHARGE See *Charge, Electric*

ELECTRIC COLUMN See *Column, Electric*, and *Volta's Pile*

ELECTRIC CONDUCTION See *Conduction, Electric, Conductor*, and *Resistance, Electric*

ELECTRIC CURRENT See *Current, Electric*

ELECTRIC DISTRIBUTION See *Electrostatics*, second part

ELECTRIC EGG An apparatus used for showing the phenomena accompanying the discharge of electricity through a partial vacuum In its primary form it is an oval shaped glass vessel with an open neck at each end To one opening is fitted a brass tube with a stop cock, which is arranged so that it can be screwed down to the plate of the air pump, and a brass rod carrying a ball projects from it into the interior The other neck is also furnished with a brass fitting, through which a second brass rod, tipped with a ball, can slide, air tight, in and out The egg is exhausted, and thin wires from the Rhumkorff's coil are attached to the upper and lower brass fittings, and the discharge thus made to pass between the two brass knobs gives rise to the most beautiful luminous phenomena The negative ball is surrounded with a blue or purple aureola, while red streams of light issuing from the positive ball widen out so as to fill almost

completely the oval-shaped interior It was observed by Grove that under certain circumstances, the light presents a *stratified* appearance, and is composed of layers alternately bright and dark, whose general lie is at right angles to the line joining the balls Since that time (1852), the electric egg has attracted the attention of some of the greatest observers, of Grove, Gassiot, Plucker, Robinson, and others The phenomenon of stratification is easily shown, when a few drops of alcohol, ether, or oil of turpentine are introduced into the egg, and the exhaustion carried down to a twelfth of an inch of mercury The light is then divided into lenticular masses, separated from each other by thick dark beds The general lie of these layers is, as we have said, perpendicular to the line joining the balls, but they are curved at each end of the egg, turning a concave side towards the balls This is particularly shown in the red light which streams from the positive extremity The blue aureola round the negative ball, is seen to be divided into two or three distinct envelopes, and a thick, dark space separates this blue light, which clings closely around its ball, from the diffused light which spreads out from the other When various gases are introduced into the egg, the phenomena are exceedingly varied and complicated The colour of the light is altered and depends upon the nature of the gas introduced With hydrogen it is greenish blue, with oxygen, much the same as in the case of air, but whiter In nitrogen, it is similar but more red at the positive end, while at the negative end it assumes a very intense dark blue With carbonic oxide, it is bright green, yellow at the positive end and blue at the negative, with carbonic acid gas it is white, and an intense blue, varying to purple, is obtained with sulphurous acid gas and with ammonia Frequently, also, the gases become phosphorescent, and continue to glow and flash after the discharge has been stopped E Becquerel has studied the phenomena of phosphorescence, and has come to the conclusion that it may arise from two causes, either from the glowing of the molecules of the gases themselves, or from the electrification of the interior of the glass, which gives rise to after discharges from place to place

The action of a powerful magnet upon the electric discharge through a vacuum, has been studied by Gassiot and by Plucker The results of Plucker are given in Poggendorff's *Annalen* Nos civ, cv, and in the *Phil Mag* for 1858, vol ii He shows that the discharge concentrates itself into a band or bands in the direction of the magnetic curves, the position and form of the bands depending upon the position of the poles with respect to the points between which the discharge is taking place He considers the case to be that of an electric current taking place through a *flexible conductor*, and inquires what must be the position of the conductor for equilibrium

The investigations which we have spoken of have been largely carried on by means of what are known as *Gassiot's Vacuum Tubes* Mr Gassiot, for the purpose of experimenting on this subject, made use of glass tubes of various sizes and shapes, through which platinum wires pass sealed into the glass, and which are once for all exhausted and hermetically sealed The idea was taken up by Geissler of Bonn, who, with the advice and assistance of M Plucker, constructed tubes of very varied forms filled with different gases, and at all degrees of exhaustion Vacuum tubes are now universally made use of, not only for the purpose of investigation, but also for lecture illustration

The cause of the phenomena which we have described is still a matter of uncertainty The origin of the stratification has been discussed by Grove, Gassiot, Robinson, by Quet, Seguin, and Morren, but it cannot be said that any satisfactory explanation of them has yet been offered

We refer the reader for further information to Plucker's papers mentioned above, and to those of Dr Robinson (*Phil Mag* 1859)

ELECTRICITY (ἤλεκτρον, amber) A name applied to that which is the cause of certain phenomena of attraction and repulsion, certain luminous appearances and physiological effects Electricity is generally spoken of as though it were a fluid or fluids, (see the concluding part of this article, and *Electricity, Theories of*), and it is in this way that we shall use the word throughout this book It is however to be understood that we *know* nothing of the real nature of electricity, and that this conception is only used in order to give definiteness to our language and our thoughts What we do know are the phenomena which electricity gives rise to, and these we proceed to treat of

According to the plan of this work the various phenomena, facts, theories, &c, are treated of under their special names or designations We propose in this article to give a very brief statement of the fundamental facts regarding electricity, and to point out where special information may be found

As early at least as the time of Thales, the fact that *amber*, when vigorously rubbed, acquires the property of drawing to itself small light bodies, such as shreds of paper, wool, &c, was known The same is said to have been observed, with respect to one or two other substances, by the Greeks, but these remained isolated facts, and the study of the science cannot be said

even to have commenced till after the publication of Dr Gilbert's *Tractatus de Magnete* in 1600, in which he treats of the forces of electric and magnetic attraction Since that time it has, on the one hand, been perhaps the most popular of experimental sciences with the exception of chemistry, while, on the other, it has given food for speculation to the minds of the greatest mathematicians, and the study and examination of the laws of attraction, and repulsion, and of electric distribution, have been among their favourite labours

Nor is the interest of the study great only to philosophers, or confined to naturalists and mathematicians On the one side the phenomena are attractive even to the most unlearned, and on the other the practical applications of electricity have already become, and are daily becoming more and more absolutely essential to our common comfort

We proceed to describe one or two experiments which illustrate the fundamental facts of this science

1 Take a thick stick of sealing wax or shell lac, carefully dried from all moisture which is best done by heating very slightly before a fire, and rub it briskly with a piece of thoroughly dry flannel Excitement, similar to that observed in amber by the Greeks, is thus produced If the rod of wax be brought near to any small light bodies, such as small shreds of paper, bits of wool, or a light feather, attraction will be at once displayed, and the bodies will fly through the air to the wax On a dry day, and with vigorous rubbing, a crackling noise will be heard, and in the dark flashes of light will be seen, while the rubbing proceeds, or if the stick of wax be brought near to the hand or face of the experimenter The excitement disappears after a time, but may always be restored by simple friction

(2) Let a light ball of elder pith, a quarter of an inch in diameter, be suspended by a fine very dry thread of silk from a convenient stand, and let the wax, after being briskly rubbed, be brought near without touching the ball Attraction will take place, and the ball be drawn aside from the vertical, but if the wax be removed, the ball falls back to its place again

(3) If the wax be brought near enough, the ball flies to it, but the moment it has touched the wax, it is, instead of being attracted, powerfully repelled, and it now remains for a considerable time repulsive of the wax, unless it be touched by some other body

(4) If under these circumstances a warm dry glass rod or tube be rubbed with a dry silk handkerchief, and presented to the pith-ball now repulsive of the wax, it will be found to attract the ball, but after contact has taken place there will be repulsion between them

(5) Lastly, if after the pith ball has been touched, either with the wax or with the glass, and the similarly suspended ball be brought near the first, it will be found that attraction takes place between them, but that after they have been in contact they repel each other

The consideration of these experiments leads us to the following fundamental remarks respecting electricity

First, we see the production of electricity by friction, and the manifestation of electric force by means of attractions and repulsions produced by it

Next, we notice the dual nature of the force, for we have seen the wax excited by friction attracting where the glass also excited by friction would repel, and glass attracting where wax would repel

Then we observe that electricity may be communicated by contact from an electrified body to one not electrified

And finally, we have an indication of the following laws —That electrified bodies attract neutral bodies, that similarly electrified bodies repel each other, and oppositely electrified bodies attract each other

Among the earliest discoveries in the science of electricity was this, that some bodies when rubbed gave apparently no electricity whatever, and hence bodies were divided into two classes, *electrics* or those which can be electrified by friction, and *non electrics* or those which cannot, and the chief effort of the earliest experimenters in the subject was the separating of bodies into these two groups, but it was soon found that this distinction is merely apparent, and that the difference depends upon what is called the power of *conduction* for electricity, which bodies possess in greater or less degrees Thus it was observed that, while a rod of glass or of sealing wax might be excited by rubbing, no amount of friction would electrify a rod of iron held in the hand But if we suppose for the present an electric fluid produced or set free by rubbing, we may imagine the fluid passing over the surface of a body such as iron or through its mass and unable to move over or through sealing wax or glass When then the electricity is produced by friction upon glass, it remains where it was produced, "insulated" as it is called, and exhibits its effects of attraction and repulsion towards external objects, but if it be produced on such a body as a rod of iron held in the hand, it is transferred through the iron to the hand, thence through the body to the earth And this is found to be the case, for if the iron rod be cemented to a stick of glass and thus supported, it can readily be electrified by friction

The transference of electricity from one point to another through or over the surface of a mass of matter is called *conduction*, bodies by means of which the transference takes place, are called *conductors*, those which do not permit it to take place are called *non conductors* or *insulators*. It was Gray who, in 1729, first showed the phenomenon of conduction, and Du Fay immediately after pointed out that electrics are identical with non conductors, and non electrics with conductors. Among conductors are the metals, graphite, water, among non-conductors or insulators are glass, sealing wax, gutta percha, paraffin, &c, and all gases. For further information, see *Conduction*, *Conductor*, *Electrics*.

It is found that all bodies may be electrified by friction, if proper precautions, such as those we have just mentioned, be taken, and that some are electrified like glass rubbed with silk, and others like wax rubbed with flannel. If we use a testing body such as the suspended pith ball, or *electric pendulum* as it is called, and electrify it in a known way, we shall be able by its attractions and repulsions to distinguish between bodies electrified one way, and bodies electrified the other. Instruments more delicate than the electric pendulum are constructed for the purpose of testing, and they are called *electroscopes*, (*q v*). By means of such instruments a division is made, and bodies electrified like glass rubbed with silk are said to be *positively* or *vitreously* (*vitrum*, glass) *charged*, while bodies electrified like wax rubbed with flannel are said to be *negatively* or *resinously charged*.

In the experiments described above, two bodies were rubbed together, but only one of them was examined in each case. If, however, the rubber is tested, it is also found to be electrified, but the electricity which it contains is of the opposite kind to that produced on the body rubbed. Thus the wax and flannel being rubbed together, the wax is, as we have seen, negatively electrified, and, at the same time, the flannel is positively electrified. In fact both electricities are produced together, and in exactly equal amounts. The kind also of the electricity produced in any particular substance by friction depends upon the body with which it is rubbed, and in the state of the surfaces rubbed together. Thus glass rubbed with silk is positively electrified, rubbed with cat's skin it is negatively electrified, while glass, with its surface ruffled, become negatively charged by rubbing with silk.

The following is a list of various substances arranged, so that if any two of them be rubbed together, the one which stands nearest to the beginning becomes positively electrified, the other negatively —

Cat's skin	Wood.	Glass	Sulphur
Flannel	Shell lac.	Cotton.	Caoutchouc
Ivory	Resin	Silk	Gutta percha.
Rock Crystal,	Metals	The Hand	Gun cotton

Electrification may even be produced by rubbing together two bodies of the same material whose surfaces differ in some way from each other. Thus if a rough and a smooth surface of the same material, or a warm and a cold surface, be rubbed together, the smoother or the colder becomes positively electrified, the other negatively. When two silk ribbons are rubbed across each other, that which is longitudinally rubbed becomes positively electrified, and when a white ribbon is rubbed by a black one, the white ribbon becomes positive. Electrification also takes place when a stream of air is directed from a pair of bellows on a glass plate, and a very powerful electric machine has been constructed to utilise the electricity produced by wet steam blowing out through a narrow pipe. (See *Electric Machine*.)

Friction is one of the chief modes of producing electric excitement, and since for the performance of electrical experiments it is frequently an object to obtain considerable quantities of electricity, machines for the purpose of producing it by friction under the most favourable circumstances have been constructed, full descriptions of them will be found under the head *Electric Machine*. But besides friction there are other sources of electricity. After cleavage or pressure certain laminated minerals, such as mica, arragonite, calcareous spar, exhibit strong electric excitement at the surfaces cleft or pressed, one of these surfaces being always positive, and the other negative, and many other bodies, not minerals at all, possess the same property. Thus if a disc of cork and a disc of caoutchouc be pressed together, and then separated, the former is found to be electrified positively, and the latter negatively. Change of temperature also produces electric excitement. If a crystal of tourmaline be warmed, it shows positive electricity at one extremity of its principal axis, and negative at the other, and if it be broken during the heating, each of the parts is electrified at each end, just as the whole was, showing apparently that the crystal possesses electric polarity analogous to the polarity which a magnet has. If the heating be discontinued, the polarity is lost for a moment, but as soon as cooling begins it is restored, now, however, the end which was positive before is negative, and that

which was negative before is positive. Topaz, boracite, and some other minerals exhibit similar action under the influence of heating.

There are several other sources of electricity, such as by the motion of magnets, which is treated of under *magnetic electricity*, and by the application of heat to a junction of two dissimilar metals, (see *Thermo electricity*, *Thermopile*), but the only one which we shall refer to now is that by chemical action. If a plate of copper and a plate of zinc be partially immersed in a vessel of non conducting material containing sulphuric acid and water, the ends of the copper and zinc plates which project from the liquid are found to be electrified respectively, positively, and negatively; if then these ends are connected for an instant by a wire, a flow of electricity takes place, and the ends are discharged; but immediately the ends are recharged, and a second application of the wire is necessary for discharging them. This goes on again and again; and if, instead of applying the wire, and then removing it time after time, the wire be kept connecting the ends of the copper and zinc plates, a steady flow of electricity takes place through it. During this time the sulphuric acid is attacking the zinc and dissolving it away; and since, according to one of the theories on the subject, it is the solution of the zinc by which the electricity is produced, we are accustomed to speak of the electricity as produced by chemical action. Since also in all the cases which we have mentioned before, such as electricity produced by friction, the electricity was insulated and at rest; and since in this case the electricity is in motion, a constant charging and discharging going on, it is customary to speak of electricity at rest, and electricity in motion; or, using terms similar to those employed in the study of mechanics to speak of *electrostatics* and *electrodynamics*, under which heads, and that of *Battery*, *Galvanic*, full information on the effects of electricity in these two states will be found. The reader should also consult *Current*, *Electric*; *Galvanism*.

We shall now proceed to notice briefly the phenomena of *induction* (see also the article under that head), and shall then conclude by referring to the theories of electricity. If an electrified body be brought near to an unelectrified and insulated body, the latter becomes electrically excited. Thus if we bring a charged metallic ball, insulated by being suspended from a silk string, near to another metal ball, or preferably, for the sake of explanation, to one end of a metal cylinder with hemispherical ends, which is set upon a glass support, we shall find the cylinder electrified in the following manner. The end nearest the suspended ball possesses electricity of the opposite kind to that of the ball, and the excitement is greatest at the place nearest to which the ball is. This gradually diminishes as we approach the middle zone of the cylinder where there is no electrification, and from this, as we approach the other end, we find electricity of the same kind as that upon the ball, gradually increasing, and greatest at the point farthest from the ball. This excitement is said to be due to *induction*, and the electricity at the two ends of the cylinder is said to be *induced*. If the inducing ball be removed equilibrium is restored, and the state of the cylinder is again perfectly neutral; but if, while the inducing ball is near to the insulated cylinder, the latter be touched or disinsulated in any way, electricity of the same kind as that of the ball flows away to the earth; and if insulation be restored, and the ball then removed, the cylinder will be left charged with electricity opposite in kind to that of the inducing ball, and exactly equal in amount to that which has flowed away to the earth. The extent to which induction takes place depends upon the amount of electricity on the inducing body upon the distance between the two bodies, and upon the nature of the insulating medium across which the induction takes place. In the experiment which we have described air was the medium interposed between the ball and the cylinder, or the *dielectric*, as it is called, but had a plate of glass been interposed induction would still have taken place, and the amount of electricity induced would have been greater. (See *Induction*, and *Capacity, Specific Inductive*.)

To explain the phenomena of electricity, two theories have been put forward; one, that of Du Fay and Symmers, known as the double fluid hypothesis, and the other, that of Franklin, commonly called the single fluid hypothesis.

The former supposes the existence of two fluids, the vitreous and the resinous, which have this property that each repels itself and attracts the other. In a neutral body, these two fluids are supposed to be present in equal quantities, and to be combined together. Friction has the effect of separating them and giving one fluid to the rubbing body, and the other to that rubbed. When a body, possessing electricity of one sort, is brought near to an insulated conductor, the neutral fluid upon it is, as it were decomposed. The kind of electricity opposite to that in the inducing body, is attracted towards that body, while the opposite kind is repelled as far as possible from it. The air, being a non-conductor, hinders the electricity from passing off the surface of an electrified conductor. The attraction of a neutral body is thus explained. The neutral fluid is *decomposed*, as it is frequently said, by induction; the opposite kind of electricity being drawn to the side nearest to the electrified body, and an equal amount of the

like kind being driven off to the opposite side But (see *Electrostatics*), the attraction due to the former is greater than the repulsion due to the latter, owing to the greater proximity of the former to the electrified body, and hence attraction on the whole prevails

According to Franklin's single fluid hypothesis, all bodies are furnished with an electric fluid which possesses the properties of attracting matter, but of repelling other portions of itself A body containing a certain quantity of this fluid, which corresponds to the quantity of matter in it, is said to be saturated, and is neutral that is, it possesses neither attraction nor repulsion for other neutral bodies This is the ordinary condition of matter But by friction, and by other means, an excess of the electric fluid may be communicated to a given body, or the quantity which it has in the neutral state, may be diminished In the first case, it is said to be charged positively, and in the second negatively This is the origin of the terms positive and negative In either of these states it is electrically excited, and exhibits the phenomena of attraction and repulsion

The advantage of these theories is, that they give us definite language, and, to a certain extent, serve to explain, or rather to illustrate electric phenomena, and both have done good service in fixing the ideas, and in assisting arrangement, but the conception of such fluids is difficult, and though one of these theories may be more possible than the other, neither can be said to be in any degree proved The explanation of the phenomena of induction given above, is certainly untrue, or at least incomplete For the theory of Faraday, consult *Induction*

ELECTRICITY, ANIMAL Galvani ascribed the current observed by him, in the case of a recently killed frog, under certain conditions, to animal electricity Volta denied altogether this explanation (See *Galvanism*) Since that time animal electricity has been the subject of much discussion, and numerous investigations have been made with regard to it

Nobili showed, by means of the galvanometer, the existence of a current in the frog from the feet to the head Taking two vessels containing salt and water, he caused the crural muscles of the frog to dip into one, and the lumbar nerves to dip into the other, then on putting into each of the vessels a wire coming from a very sensitive galvanometer, he obtained a current in the direction mentioned Nobili calls this the *courant propre* of the frog

Matteucci experimenting on the same subject formed a pile of the thighs of frogs by putting the interior of the muscle of each thigh in contact with the exterior of the muscle of the succeeding one He showed a current proceeding from the interior to the exterior of the muscle

Dubois Remond has shown the existence of muscular currents in the human body

ELECTRICITY, APPLICATION OF The applications of electricity have become extremely numerous and are daily becoming more and more so Throughout this volume will be found, as far as our limits will allow, indications of the various uses to which it has been put, both in the way of aids to the arts, and as an auxiliary to our daily life Here we may mention its application to electro metallurgy in various forms, and to illumination, also in the electric clock, and electro-magnetic machine, and for purposes of self registration, in observatories and elsewhere Telegraphy is one of its most important uses, and lately its physiological effects have been taken advantage of in a systematic and scientific way by the physician To the chemist also its agency is invaluable

ELECTRICITY, ATMOSPHERIC See *Atmospheric Electricity*

ELECTRICITY, CORRELATION OF It is explained (see *Transmutation of Energy*) that physical force can no more be *destroyed* than matter, but, on the other hand, that all the forces are convertible one into the other And not only is this true, but the disappearance of a certain amount of one kind of energy always gives rise to the appearance of a *perfectly definite amount* of energy in another form Dr Joule and Sir William Thomson investigated the question in the case of electricity

It is well known (see *Current, Heating Effects of*) that when an electric current passes through a fine wire an amount of heat is generated which depends upon the strength of the current, and also that when a wire is wrapped round a cylinder of soft iron a definite amount of magnetic force is developed which depends upon the strength of the current (See *Electro-magnet*) Joule and Thomson showed that the quantity of electricity which, when converted into heat, would raise the temperature of one pound of water through 1° F, would, if converted into mechanical effect, raise one pound of matter through 772 feet

Again, water is decomposed by the electric current into oxygen and hydrogen (see *Electrolysis*), and these gases, on being mixed and exploded, produce heat (See *Heat of Combination*) The same quantity of electricity which would, if turned into heat, raise one pound of water through 1° of temperature, would, if applied to work against the chemical forces which hold together oxygen and hydrogen, separate a quantity of these elements such that, if exploded, it would produce precisely the same amount of heat

Thomson also determined the mechanical value of certain distributions of electricity and magnetism, but for these mathematical investigations we must refer the reader to his papers published in the Transactions of the Royal Society, also, for further particulars, to the papers of Joule, Transactions of the R S from 1840, and to Grove's *Correlation of the Physical Forces*

ELECTRICITY, PHYSIOLOGICAL EFFECTS OF The passage of the electric discharge through the animal body produces peculiar physiological effects On touching a charged Leyden jar, and permitting its electricity to pass through the body, a sensation is experienced which it is not easy to describe Apparently, the muscles swell up violently and suddenly, and the sensation felt might, perhaps, be described as that of a blow throughout all the parts of the body, but lasting only for a moment When the discharge is only weak, the hands and wrists experience the *shock*, but with more powerful discharges it extends as far as the shoulders, and even throughout the chest Such discharges are, however, dangerous The discharge may be passed through a large number of persons at the same time By forming a circuit, in which each person is in contact with his neighbour on each side, a shock is felt by all when the first and last touch one the inside and the other the outside coating of the jar

The shock may easily be so powerful as to destroy life No great quantity of electricity is required to kill animals, such as mice, rats, or small dogs

The physiological effects of current electricity are also peculiar With a battery of 30 or 40 cells a powerful shock is felt when the circuit is opened or closed by the hands

When the terminals of the battery are applied one above and the other below the tongue a peculiar sensation or taste is felt, which has been called the *electric taste* With a strong battery it is more of the nature of a stinging sensation than of a taste, but the impression produced by a single cell is decidedly that of a taste The electric taste is an excessively delicate test of an electric current Signals may be tasted which even a delicate galvanometer will fail to detect

If two metallic slips be placed between the gums and the cheeks, one on each side, and one of them kept connected with one pole of a battery while the other is joined to the other pole at intervals, at each junction a flash of light is seen before the eyes

If the electrodes of a strong battery, 30 or 40 cells, be inserted into the ears, a noise is heard continuously

ELECTRICITY, THEORIES OF Leaving out of account the more ancient conjectures on the subject, two principal hypotheses have been put forward, in order to explain known electrical phenomena, and though perhaps neither represents the true state of the case, they are, nevertheless, of high practical value in enabling us to fix our ideas, and in supplying us with definite thoughts and language They are generally known as "the double fluid hypothesis of Dufay and Symmers," and "the single fluid hypothesis of Franklin"

The first supposes all matter to be pervaded by two imponderable fluids, one of which is called the *vitreous* fluid (*vitrum*, glass), and the other the *resinous* fluid, and to each of these are ascribed the properties of attracting the other, and of repelling other portions of itself When in every portion of a body the two are associated in equal quantities, the body is neutral, that is to say, is not electrically excited, but when either preponderates the body is excited, and is said to be electrified *vitreously* (like glass rubbed with silk), or *resinously* (like wax rubbed with fur), according as it possesses a superabundance of the vitreous or of the resinous fluid (See article on *Electricity*) It follows from what we have said that if a body *charged* vitreously be brought into the neighbourhood of a body charged resinously, attraction takes place, whereas, if a vitreously or resinously excited body be brought near a second similarly electrified, repulsion is manifested between them The attraction of a neutral body by an electrified body was explained by supposing the intimately mixed fluids on the former to be separated under the influence of the latter, the unlike fluid to be attracted to the near side, and the similar fluid to be repelled to the opposite side of the mass The unlike fluid being thus nearer than the like fluid the attraction exerted by the former on the charged body on the whole prevails over the repulsion exerted by the latter according to the well-known quantitative laws depending upon distance (See *Electrostatics*)

The other hypothesis, namely, the single fluid hypothesis, supposed only one fluid to which Franklin attributed the properties of attracting matter, and of repelling other portions of itself He was also obliged to consider that two portions of matter unsaturated with this fluid exercised repulsion on each other He called a body *neutral* when the matter that it contained possessed exactly enough of the fluid to saturate it, and in this case it possesses neither attraction nor repulsion on other neutral matter. A body which possessed an excess of the fluid, he said, was *positively electrified*, and a body which possessed a quantity of the fluid less than it would have in the neutral condition, he spoke of as being *negatively electrified*

ELECTRICITY, VELOCITY OF The problem of determining the velocity of electr-

city has been undertaken by several naturalists with great care, and with results which we shall briefly detail in this article It was first attempted by Wheatstone in 1834 with an instrument invented by him for the purpose, and known under the name of the *Chronoscope* This consists of a mirror rotating with enormous velocity, which velocity he measured by means of the musical note produced in another part of the apparatus by the same motion In front of the mirror a *spark board* was placed, which was a circular block of wood in which were set in a row six wires carrying small knobs, and round these and over the face of the wood was a thick coating of some resinous insulating compound The outer coating of a Leyden jar was connected with the first of the knobs, between the second and third a quarter of a mile of copper wire was inserted, and also a quarter of a mile between the fourth and fifth When an experiment was to be made the sixth knob was connected with the inside coating of the jar The discharge then took place in the following way a spark passed from No 6 to No 5, the electricity had then to traverse a quarter of a mile of copper wire to reach No 4, a spark occurred between No 4 and No 3, then came the second coil of wire, and, lastly, the spark passed from No 2 to No 1 Now, if the three sparks all occurred at the same instant, the reflection of them in the mirror would all be seen side by side in a row, but if one of them occurred later than another, the mirror would have turned onward through a small angle, and the image of the sparks would exhibit this retardation The latter was found to be the case, and from measurements made in this way Wheatstone estimated the velocity of electricity at 288,000 miles per second, a rate at which it would travel twelve times round the earth in one second

Subsequent investigation showed, however, that it is impossible to express the velocity of electricity absolutely, and that it depends very much upon the circumstances under which the signal is transmitted The following table of results shows this

	Nature of Wire	Velocity in Miles per Second
Wheatstone, 1834,	Copper	288,000
Fizeau and Gonelle	Copper	111,834
" "	Iron	62,130
Mitchell (Cincinnati)	Iron	28,331
Walker (America),	Iron	18,639
Gould,	Iron	15,830
Astronomers of Greenwich and Edinburgh,	Copper	7,600
Astronomers of Greenwich and Brussels,	Copper	2,700
Atlantic Cable, 1857, 2,500 miles with heavy needle galvanometer and induction coils	Copper	1,430
Atlantic Cable, 1858, 3000 miles, Thomson's mirror galvanometer, and Daniell's battery,	Copper	3,000

The explanation of the meaning of these discrepant results was begun by Faraday, and was completed by Sir William Thomson, who gave, (in papers communicated to the Royal Society, 1854 to 1856, and published afterwards in the *Philosophical Magazine*), a complete investigation of the laws of electric retardation Faraday showed that if an electric cable, consisting of a wire or wires covered with gutta percha, be submerged, it acts precisely as an enormous Leyden jar would under the circumstances The wire forms the interior coating, the gutta percha the insulating medium, while the water, in which it is immersed, takes the place of the exterior coating He proved that, under these circumstances, a certain time is necessary to charge the cable, and that, after communication has been cut off from the battery, a certain time is also required, on putting it into communication with the ground, to discharge it, but if, instead of submerged wires, he made use of wires freely suspended in the air, these phenomena were scarcely at all exhibited, what retardation there was being possibly, to some extent, dependent on electrostatic induction towards neighbouring objects Wheatstone also made some experiments, which proved that a cable, consisting of a copper wire covered with gutta percha, and having a sheathing of wire outside, even though not immersed, gave precisely the same results arising from induction, as Faraday had observed the wire covering acts in this case as the outer coating Sir William Thomson thus states his theory (see the papers just referred to, and an article by him on the subject in Nichol's Cyclopædia, Second Edition) The transmission of an electric signal depends on three properties of electricity (1) Charge and electrical accumulation in a conductor subjected in any way to the process of electrification (2) Electro magnetic induction, or electro motive force, excited in a conductor by variations of electric currents, either in adjacent conductors or in different parts of its own length (3) Resistance to conduction through a solid He draws the analogy between the transmission of a signal, and the sending of water through a canal or tube, which depends on—(1) Accumulation of a greater or less amount of water in any part of the canal or tube, (2) Inertia of the

water, and (3) Viscosity or fluid friction, and he shows that, supposing the tube to be filled with porous or spongy matter, in order to make the law of resistance to the motion of the fluid the same as the law of electric resistance, the two problems present the same elements for mathematical calculation, and the same equations express the law of motion in both cases He proves, also, that the retardation due to electro magnetic induction is insensible, and that on the first and third properties depends the whole of it According to this theory, the difference between the rate of transmission of signals, in a short line insulated in the air, and in a long submarine cable, depends upon the way in which the electrical impulses traverse the wire In the former case the electrostatic capacity is extremely small, and the wire is at once filled and at once discharged, in the latter the discharge takes a considerable time for its completion There is a "long gradual swell, and still more gradual subsidence of the electric current" at any distant part of the conductor and the length of time that elapses between the moment of the initial impulse and the attainment of maximum strength, or of any proportion of the maximum strength, is proportional to the square of the length of the line "The beginning of the current is instantaneous all along the line, and is practically observable after a smaller and smaller interval the more sensitive the instrument employed to detect it" This last observation is seen to be verified on referring to the velocities, calculated from observations, with the heavy needle galvanometer, and with Thomson's mirror galvanometer.

ELECTRIC IMAGES See *Images, Electric*

ELECTRIC LAMP See *Lamp, Electric*

ELECTRIC LIGHT The luminous effect of the electric current forms one of the most striking phenomena connected with it When the terminals of a very powerful battery are joined, and then very slightly separated, the electric current can be made to pass through the air, giving rise to the most intense light and heat In order to exhibit it the wires coming from the battery are connected with a mechanical arrangement, by means of which two *carbon points* can be made to touch, and then separated to any required distance from each other If the wires themselves were made use of the intense heat at the point where the separation takes place would at once melt and destroy them The carbon points are best made from the hard gas carbon, a substance which is found deposited in the heads of the gas retorts It is cut into pencils or else powdered, and then compressed in a mould into the required shape We thus obtain terminals of very high conducting power, and which remain infusible even under that intense heat The points of these being brought together the current is set up, they are then withdrawn as far as possible, in the case of a battery of 50 cells the distance may be a tenth of an inch or more, and immediately the most dazzling pure white light appears, so brilliant indeed that it is almost impossible to look at it safely with the naked eye On examining the charcoal points with the aid of coloured glasses, or by projecting an image of them on a screen by means of a lens, it is found that the greater part of the light proceeds from the tips of the carbon, which are heated to intense whiteness Part of it also comes from a flame which is seen between and around them, and which consists of small particles of carbon in motion from one to the other, and in a state of incandescence The positive pole is the most intensely heated for on stopping the current it will be found to remain red hot for some time after this other has ceased to be so The light is not produced by the combustion of the carbon, or at least only to a small extent, but from the bringing of the solid particles into a state of intense white heat This is shown by the fact that the light burns under water or oil, or any non-conducting fluid, though with diminished brightness, and that in vacuo it is obtained with its brilliancy very much increased

During the passage of the electric current the particles of the carbon are carried from the positive poles They are partly burned on the way, and partly reach the negative pole Both the poles waste away, but the positive pole at double the rate of the negative pole The positive pole also has a hollowed out appearance, owing to the carrying off of its particles, while the negative pole, which is receiving particles from it, has a pointed form It is the passage through the air of these particles which gives rise to the appearance of the arch of flame between the two poles.

The arch of flame is called the *Voltaic arc* It is the most intense artificial heat that we possess In it platinum wire and even such a refractory body as clay, the stem of a tobacco pipe, for example, may be melted as sealing-wax in the flame of a candle The fusion of metals like platinum, iridium, &c, is performed by placing them in a small cup or crucible formed of gas carbon, which is substituted for the point attached to the positive pole. The other point is then brought down upon the metal, and, with the assistance of twenty or thirty cells of a battery the fusion readily takes place

The wasting away of the poles soon causes the distance between the points to become so great that the current will no longer pass The points must then be pushed forward to touch

again, and again withdrawn Automatic arrangements are made for adjusting the points as required, so that the distance between them may be invariable. These are described under *Lamp, Electric*

ELECTRIC LIGHT, PHOTOMETRIC VALUE OF Professor W B Rogers (*Silliman's Journal*, vol xxxvi, p 307) has given the results of some experiments which he tried on this subject The battery was very powerful, consisting of 250 carbon elements, each having an active zinc surface of 85 square inches They were grouped in five batallions of 50 each, and the light was produced in an apartment where a range of about 50 feet could be obtained for the photometric apparatus Instead of an ordinary standard light, equivalent to 20 candles, a unit was substituted ten times as great, equal therefore to 200 candles By a series of experiments, with the naked electric light unaided by a reflector, it was found that its intensity was from 52 to 61 times as great as the standard light, making it equal in illuminating power to from 10,000 to 12,000 standard sperm candles When the rays were concentrated by a parabolic reflector, the illuminating force had a value equal to several millions of candles, all pouring forth their light at the same time The only previous measurement of the illuminating power of the electric light which we can remember is one given by Bunsen This was taken with a less powerful battery (48 cells), and the photometric equivalent was estimated at 572 candles, giving a proportion of 12 candles to the cell, whilst Professor Rogers' estimate gives the ratio of 40 candles to the cell (See *Photometry*)

ELECTRIC LIGHT, SPECTRUM OF THE The spectrum of the electric light is of a highly complex character The intense heat of the arc dissipates into vapour almost every substance contained in the terminals, and as the carbon points are always contaminated with small portions of iron, together with earthy and alkaline compounds, the spectra of these bodies are generally visible Besides these the lines due to oxygen, nitrogen, and sometimes aqueous vapour and carbonic acid, are visible The electric light is extremely rich in the actinic or ultra violet rays (See *Actinism*, *Spectrum*)

ELECTRIC MACHINES The principal forms of electric machine now in use are the *Cylinder Machine* and the *Plate Machine*

The *Cylinder Electric Machine* is constructed in the following way A glass cylinder is supported by means of a horizontal axis on two wooden uprights, and is turned by a handle attached to one extremity of the axis Parallel to the glass cylinder are two of brass, one on each side of it equally long with it, but of smaller diameter, and these are supported on glass pillars fixed into a wooden table or board, which also carries the wooden uprights To one of the brass cylinders is attached a cushion as long as the cylinder itself, it is made of horse hair, and covered with leather, and, by means of a spring or a screw, it is kept pressing against the glass cylinder A long flap of silk is attached to the lower edge of the cushion, and, when the machine is at work, it passes between the cushion and the glass cylinder, and lies over the latter, covering the whole upper half of it The portion of the silk which covers the cushion is spread with electric amalgam (See *Amalgam, Electric*) The other brass cylinder, which is called the *prime conductor* of the machine, is furnished with a horizontal row of pointed wires, like a comb, with intervals of half an inch between its teeth, which project towards the glass cylinder, approaching as nearly as possible without touching it

When the glass cylinder is turned it becomes positively, and the cushion negatively, electrified by friction The positively electrified glass is carried round till it comes opposite to the points belonging to the prime conductor The prime conductor becomes excited by induction, and in fact, is electrified negatively on the side nearest to the glass, and positively on the side opposite to the glass But the points have no power to hold a charge (See *Power of Points*, *Electric Distribution*, under *Electricity*), and they discharge towards the glass cylinder, permitting negative electricity to flow from themselves towards it, and thus they neutralise the positive electricity on it, and, as will readily be seen, leave the prime conductor charged with positive electricity A spark of positive electricity can now be obtained from the prime conductor But, during this time, the cushion has, as we have mentioned, been charging with negative electricity, and when it has attained a certain degree of electrification, it is necessary to discharge it before any more positive electricity can be obtained from the prime conductor This could be done by touching it, and sparks of positive and negative electricity could thus be alternately produced, but, instead of doing this, it is usual to connect the cushion permanently by means of a chain or wire to the earth, and then, on turning the machine, a continuous discharge of positive electricity can be got from the prime conductor

The Plate Electric Machine is the same in principle as the cylinder machine, but instead of a glass cylinder, a circular glass disc or plate, ¼ inch or more in thickness, and from 3 to 5 feet in diameter, is used There are several modifications of the plate machine That of Ramsden is, perhaps, the most common, and in almost every respect corresponds to the cylinder machine.

That designed by Winter of Vienna is the most novel, and by far the most powerful We shall next describe it

In the middle of the glass plate is inserted a wooden piece which forms a socket for a strong glass rod, the axle on which the plate turns At opposite extremities of a diameter of the plate are a brass cylinder which carries the rubbers, and a large brass ball This ball, the prime conductor of the machine, has four holes opening into its centre, the edges of which are trumpet-shaped to prevent the dissipation of electricity The glass pillar which supports it fits into one of them, and into another which is on the side near to the edge of the plate fits a brass stem This last carries two mahogany rings, one on each side of the glass plate, with their planes parallel to the plane of the plate, and the electricity is collected by means of a row of points fitted into grooves on the sides of the rings next the plate The grooves are covered inside with tinfoil, which makes perfect communication with the brass ball, and the points do not project beyond the edges of the grooves The third opening in the brass ball is also horizontal, and into it may be inserted a stem with a brass ball for sparks The top opening is to carry a large ring which can be removed at pleasure To form the ring a stout iron wire is bent into the shape of a ring with a stalk attached This is carefully covered with polished mahogany, and by means of a brass wire coming through it, connection is made between the iron ring and the brass ball in which it stands The ring is one of the peculiarities of Winter's machine Its object is to give a large surface for collecting electricity which shall have as little tendency as possible to throw off electricity (See *Dissipation*) The effects obtainable from a Winter's machine are wonderful (See also *Discharge*)

Armstrong's Hydro-Electric Machine is a machine for obtaining electricity by the friction of moist steam The attention of Sir W Armstrong (then Mr Armstrong) was called to this mode of obtaining electricity by a workman who accidentally received a shock whilst testing a steam boiler Mr Armstrong designed the electric machine, and the conditions for producing electricity by friction of steam were afterwards completely investigated by Mr Faraday The machine consists of a boiler similar to that of a locomotive insulated on four glass legs To the escape pipe is attached a row of nozzles, constructed so as to give as much friction as possible to the steam which rushes out through them Round the nozzles, between their extremities, and the part at which they join the escape pipe, is a box of cold water, in order that the steam, after passing through it, may issue from the nozzles charged with vesicles of water (This was found by Faraday to be a necessary condition for the production of electricity) The steam blows against a row of points attached to a large metal ball (which is the prime conductor of the machine), insulated on a separate pillar from the boiler When the steam blows off it becomes charged with positive electricity, the boiler with negative electricity The electricity of the steam is given up to the points and prime conductor

There are many other forms of electric machine, besides those described above, for information with regard to which we must refer our readers to detailed works on electricity Lately machines, depending for their action upon statical induction, have been brought into use, and among these may be mentioned those of M Holtz, Mr Varley, and Sir William Thomson A description of the first will be found in Jamin, *Cours de Physique*, vol III, and of the last in the *Philosophical Magazine*, 1868 Mr Varley's machine is used in connection with his improvements in telegraphy, and will be found described with the specification of his patent

ELECTRIC MACHINE, INDUCTION See *Induction Coil*

ELECTRIC RESISTANCE See *Resistance, Electric*, and *Conduction, Electric*

ELECTRICS (ἤλεκτρον, amber) The earliest experimenters in electricity found that while they could excite electrically a certain class of bodies, such as amber, sealing wax, and glass, by friction, there were others which were incapable of electric excitement, and the efforts of the first students of electric science were directed to the division of all bodies into two classes, those which could, and those which could not, be excited by friction The former they called electrics, from the Greek name for amber, the chief of the exciteable bodies, and the latter class they called non-electrics, names which, it is said, were applied by Gilbert of Colchester in A D 1600 It was shown, however, by M Du Fay, that electrics and non electrics are identical with *non-conductors* and *conductors* respectively, that the reason why a brass rod is apparently unexciteable and a non-electric, is that the brass has the power of permitting the electricity as fast as it is produced to pass away along its surface to any other body, as, for example, the hand of the experimenter, and that if proper precautions be taken, such as holding the brass rod by means of a glass handle, or supporting it by a silk string, it may be excited by friction, just as easily as a rod of glass From that time the distinction between electrics and non-electrics held no longer in the original form The terms are still, however, made use of frequently (See also *Electricity*)

ELECTRIC SPARK See *Spark, Electric*, and *Discharge, Electric*.

ELECTRIC SPARK, PHOTOMETRIC VALUE OF The visibility of the electric spark is enormously greater than that of a permanent light produced by a battery of the same power M Felix Lucas concludes, from theoretical considerations, that the distance at which the electric spark is visible is greater than that of a permanent light, the apparent intensity of which would be 250,000 times that of the spark The light actually employed to illuminate modern lighthouses gives a brilliancy equal to 125 Carcel lamps An electric spark, possessing the illuminating power of the 200th part only of a Carcel burner, is superior as to its power of projecting light Hence we can conceive the immense effect of a warning light, composed of intermittent flashes of the electric spark, proceeding from a strong Leyden battery M Lucas states that in an experiment made in a laboratory two apparatus were employed, one voltaic battery being equal to 125 Carcel lamps, and another spark-battery equivalent to only the 1 2000th part of a Carcel lamp The photometer (such as is employed in the lighthouse administration) showed a marked superiority in favour of the spark (See *Photometry*)

ELECTRIC SPARK, SPECTRUM OF When the electric spark taken between metallic terminals is examined in the spectroscope, there are seen, besides the lines due to the air, a series of bright bands and lines which are peculiar to the metal of which the poles consist These lines have recently been thoroughly examined by Mr Huggins (See his paper on *the Spectra of some of the Chemical Elements* *Phil Trans* 1864, part ii, page 139) For further particulars, with maps of the spectra given by the chemical elements, the reader is referred to the above paper (See *Spectrum*)

ELECTRIC TELEGRAPH See *Telegraph*, *Cable, Submarine*, *Atlantic Telegraph*

ELECTRO-CHEMISTRY treats of the chemical changes which take place under the influence of electricity It is generally divided into several parts, and in this volume these are dealt with separately Thus, under the term *Electrolysis* is discussed the decomposition, or separation into its constituent parts, of a compound body by the passage of the electric current, and under *Electro metallurgy*, and its two branches *Electro plating* and *Electro typing*, the application of electrolysis to the arts The chemical actions which go on within the *battery* are considered under that head, but there are one or two points of importance which may be put forward here

One of the most ordinary cases in which electricity brings about a chemical change, is that in which oxygen and hydrogen, or other gases, mixed together are made to combine by the electric spark This is generally effected in a eudiometer, which is a strong glass tube, closed at one end, and usually graduated A pair of platinum wires are passed through opposite sides of the glass, being fused into it, and their points, inside the tube, are brought to within a tenth or a twentieth of an inch of each other The mixture of the gases to be examined is introduced into this tube over mercury, care being taken not to fill it completely, a column of an inch or more of mercury is left within it When the spark is to be passed, the open end of the tube is depressed considerably below the level of the mercury, over which the tube stands, and thus when the explosion, which accompanies the passage of the spark, takes place, the gas within the tube is not driven out by it

In this way a mixture of oxygen and hydrogen, in the proportion of one volume of the former to two of the latter, are made to combine together and form water After the explosion (which occurs with great violence,) has taken place, the steam, at first produced, condenses, and the mercury rushes up and completely fills the tube, if the mixture be in the proportion mentioned above If it be not, the explosion still takes place, unless there be a very large excess of either gas, the combination is, however, in the proportion of one volume of oxygen to two of hydrogen, and the remainder of whichever gas is in excess is left But if there be a very large excess of one gas,—twenty times too much hydrogen, or thirty times too much oxygen, the explosion does not take place In this case, however, on passing a series of electric sparks between the points, the formation of as much water as corresponds to the volume of that gas whose quantity is the smallest, can by degrees be brought about

The sparks may be passed from the electric machine, or from the electrophorus, or when a continuous stream is required, the spark from an induction coil may be very conveniently used

The power of the electric spark to bring about chemical combination appears, in this and similar cases, to be due to its heating effect In the case of a mixture of one volume of oxygen and two volumes of hydrogen, the combination of the molecules in close proximity to the place at which the spark passes is determined first, and the heat of combination of these is sufficient to explode those near to them Thus the combustion spreads gradually, though, of course, with immense rapidity, through the whole volume But if there be added to the mixture a very large excess either of oxygen, or hydrogen, or of some gas, such as nitrogen or carbonic acid gas, which has no great affinity for either, the cooling effect of this gas is so great, that the combustion only goes on close to the spot where the spark passes, and does not spread

throughout the mass The combination, in that case, is effected by means of a very large number of sparks The same is the case with gases which do not combine energetically Thus, nitrogen and oxygen, produce very little heat by their combination, and a single spark does not combine them, but if a series of sparks be sent through the mixture, the oxides of nitrogen are formed, and by including in the tube water or solution of caustic potash, or soda, nitric acid, or nitrate of potassium or sodium, may be very easily obtained

The combination of various gaseous mixtures may be effected in either of these ways We must content ourselves with mentioning one other important case It had been observed that, on turning the electric machine, especially if there be points attached to the prime conductor, or if sparks are being rapidly taken, a peculiar odour is produced, and the same is noticed in the oxygen which comes from the electrolytic decomposition of water *Schonbein* showed that this arises from the effect of the electric discharge on the oxygen gas around it He called the body, which he supposed to be formed, and from which the odour arises, *ozone*, and investigated the circumstances of its production and destruction Long discussion as to the composition of this body followed the publication of Schonbein's observations, but it is now generally admitted that ozone consists of oxygen condensed into a smaller bulk, and in all probability is formed by the combination of oxygen with itself (See *Ozone*)

Not only is combination effected under the influence of the electric spark, but what appears strange, the spark also produces the decomposition of a compound Thus ammonia gas is doubled in volume by the passage of the electric spark, being split up into hydrogen and nitrogen, in the proportion of three volumes of the former to one of the latter Nitric oxide under the same treatment becomes nitric acid and oxygen, and nitrous oxide becomes nitrogen and oxygen Other gases can also be decomposed The action of the spark upon a liquid is shown by causing the electric discharge to take place through the liquid between two very fine points placed at a short distance from each other Wollaston adopted the method of enclosing a very fine gold wire in a capillary tube, and heating the glass so as to fuse the wire on to the end of it and completely cover it The glass was then filed very gently away till the wire is just seen with the aid of a lens to be uncovered When sparks are passed between two such points, through water, a continuous stream of gas is seen to rise from each of the points The decomposition which occurs here is not at all the same as that which takes place when a current of electricity is sent through the liquid In the latter case oxygen rises from one plate and hydrogen from the other, but in the case of water decomposed by the spark, hydrogen and oxygen, mixed, come off from each of the points

From the experiments of Grove, it appears that in all these cases the chemical action brought about by the spark, is due to the very intense heat developed by it He showed similar combination and decomposition taking place under the influence of incandescent platinum, heated either by the passage of the electric current through it or in some other way We are unable to detail his experiments here, but refer our readers to the papers of Grove, or to the treatise of De la Rive, vol ii

ELECTRODE (ὁδὸς, a way) A term introduced by Faraday to designate a surface at which the electric current either enters or leaves a body under electrolytic decomposition He calls that the anode (ἀνὰ, upwards) at which the current enters, and that the kathode (κατὰ, downward) at which the current leaves the electrolyte (See *Anode*, *Electrolysis*)

ELECTRO DYNAMICS (δύναμις, force) Under this not very appropriate name is usually included that part of electrical science which deals with the attraction and repulsion manifested between currents and currents, and between currents and magnets In 1819 Œrsted discovered that force is exerted by a current on a magnet in its neighbourhood Ampère also examined the nature of this force, and afterwards showed a similar force existing between two currents

Ampère's fundamental law which governs the mutual action of currents upon currents is that *two currents flowing in the same direction attract each other, two currents flowing in opposite directions repel* The phenomena of attraction and repulsion are generally shown by means of wires which are made moveable by turning about an axis, and the ends dipping into concentric troughs of mercury, which are connected with the terminals of the battery In this way it may be shown that a wire carrying a current moves bodily towards a parallel wire carrying a current *in the same direction*, and is bodily repelled from a parallel wire carrying a current *in the opposite direction* Again, if two currents, one of which is moveable, are passing near to each other, their directions making an angle between them, if they are flowing in the same direction, a force is exerted between them, which tends to diminish the angle and make them flow parallel, but if they are flowing in opposite directions the moveable wire is turned completely round, and finally sets so that the wires are parallel, and the directions of the currents the same It follows also from the principles which have been stated, that if two currents are flowing at

right angles to each other, and if one of them be moveable parallel to itself and parallel to the direction of the other current, the moveable current is carried backwards, when it flows towards the other, and forward when it flows away from it.

Lastly, it is a consequence of Ampère's law that each elementary portion of a rectilinear current repels the elementary portions nearest to it. Faraday, to show this experimentally, suspended from the beam of a very delicate balance a piece of copper wire bent into the shape of an inverted U. The ends of the wire dipped to some depth into tall mercury cups which were connected with the terminals of the battery. When the current passed, this wire rose in the cups, and sank again on the cessation of the current, and the explanation given is that the current in the parts of the mercury, and of the wire near to each other, being in the same direction repel each other.

These laws are illustrated by apparatus consisting of moveable wires, such as we have mentioned above in various forms. For example, it is easy to show continuous rotation of one current produced by a current in a direction at right angles to it, which is evidently a consequence of what has been stated with regard to such currents. Let a current pass in a circle placed horizontally, or what is better, through several horizontal coils of insulated copper wire, and let another current rising through a pillar placed at the centre of the circle pass into a copper wire, turning on a pivot at the top of this pillar and dividing there, flow in two opposite radii to the circumference, then turning vertically downward, come into a horizontal circular trough of mercury into which the ends of the wire dip, and thence return to the battery; we shall thus have two currents coming vertically down, at right angles to that which is circulating in the horizontal wire, and rotation of the vertical wires will take place in a direction opposite to that in which the horizontal current is flowing. If the current is made to flow upwards in the vertical wires, the rotation will take place in the same direction as that in which the horizontal current is flowing.

Action between Currents and Magnets. Œrsted's fundamental experiment shows that when a magnet is placed in the vicinity of a current, and able to move round an axis perpendicular to its length, it sets itself at right angles to the direction of the current according to a law which is thus enunciated by Ampère. Let an observer be situated in the conducting wire, the current entering at his feet and passing out at his head, and let him look on the north pole, the rotation will be such that *the north pole will always turn to his left hand*. Thus let the wire be situated above the needle, and let the current flow from south to north, the north pole of the needle will deviate towards the west. If the wire is below the needle, the north pole will move towards the east. (See *Ampère's Law*.)

Just as the moveable magnet is rotated by the fixed wire, so is a moveable wire acted on by a fixed magnet. To show this a rectangle of wire is made to turn about a vertical axis in its own plane, and at right angles to two of its sides. On bringing a magnet near to it while a current is passing through it, the wire sets itself at right angles to the length of the magnet, and in such a direction that the north pole of the magnet is to the left hand of an observer situated as described above. For exhibiting the action of a magnet on a moveable current a beautiful little apparatus called De la Rive's *floating battery* is also employed. It consists of a very small cell attached below the centre of a circular disc of cork; the terminals of it pass through the cork, and are attached to a small vertical ring or coil of insulated wire carried on the top of the cork. When the battery is charged a current passes through the coil, and the whole apparatus may be floated on the surface of water by means of the cork. On bringing a magnet near to the coil and on a level with its centre the latter turns round and sets itself with its plane perpendicular to the length of the magnet, and turns that side to the end of the magnet which makes the current in the ring parallel to Ampère's hypothetical currents in the magnet. (See *Ampère's Theory*.) It then takes a bodily motion towards the magnet, passes the pole and moves along, making the axis of the magnet coincide with its own axis, till it reaches the middle of the magnet and there stops. If it be placed at the middle of the magnet with its plane turned so that the current in the coil is opposite in direction to that of Ampère's hypothetical currents in the magnet, it then moves off at one end of the magnet, turns round and comes back again, and takes the position of equilibrium. The attraction and repulsion of a current on a magnet give rise also to rotatory motion. Faraday showed this by the following apparatus. Through the bottom of a deep vessel containing mercury, a wire from the battery passed, and a hook connected with the other terminal of the battery sustained one end of a wire above the centre of the mercury cup, while the other dipped into the mercury, and thus completed the circuit. This wire was longer than the shortest distance from the hook to the mercury, and being buoyed up at the lower extremity assumed a position nearly vertical but not quite. In the centre of the vessel stood a vertical bar magnet with its top projecting some distance above the mercury. The current passed through the mercury into the moveable wire,

and by means of the hook which supported the latter, back to the battery, the wire then revolved round the magnet Similar rotation was shown by a magnet about a fixed current The following law governs these rotations, *Suppose an observer to be placed at the north pole of a magnet parallel to the current, and let him look at the current which appears to him to flow upward, then the rotation of the current takes place from right to left* From these and from similar experiments it appears that a portion of a current in a magnetic field tends to move so as to cut the lines of magnetic force at right angles, and in such a direction that a figure placed in the wire while the current enters at his feet, and looking at the north pole, is urged towards the right

M De la Rive has devised a beautiful apparatus for showing the rotation of an induced current passing through a vacuum (See *Electric Egg*) Into the exhausted vessel a piece of soft iron projects, which is covered with glass and shell lac, and thus most carefully insulated from the vacuum space, and it terminates outside in the centre of the wooden foot on which the apparatus stands At the top of the vessel a wire enters in the ordinary way, and at the bottom a wire projects inwards, carrying a ring which encircles the glass tube containing the soft iron The foot being set on one pole of an electric magnet, the soft iron piece becomes a magnet by induction A current is now made to pass through the vacuum, and the arc of light is seen between the wire at the top and the ring below, and under the influence of the magnet it rotates slowly round the pole, the direction depending on the direction of the current and on the nature of the pole of the magnet on which the soft iron is placed The apparatus was originally devised to illustrate the theory of M De la Rive with regard to the rotation of the Aurora Borealis, (*q v*)

As might be expected, the earth's magnetism produces an effect on currents free to move under its influence in precisely the same way that an artificial magnet acts This is demonstrated either by means of the floating current or by the other moveable apparatus which we have mentioned above The laws which govern the action of the earth upon moveable currents are precisely the same as those which hold in the case of artificial magnets, but in applying them it must be borne in mind that, according to our English way of naming the poles of a magnet, the north pole of the magnet corresponds to the south pole of the earth The following law, deduced, of course, from the general law, may be stated in particular as being very important in connection with the theories of terrestrial magnetism and with the action of the solenoid, of which we are about to speak Let a closed current in a vertical plane be capable of turning about a vertical axis, which is, for example, the case with De la Rive's floating battery, *the current places itself in a plane perpendicular to the magnetic meridian, and in such a way that the current descends to the east of the axis of rotation and ascends to the west of it*

Of Solenoids Solenoids were used by Ampère for illustrating his theory of magnetism A solenoid is constructed by winding copper wire in the form of a helix or screw on a cylinder of convenient size (1 to 1 5 inches in diameter), the ends of the wire are turned inward and brought back along the axis of the cylinder to the middle, where they are turned at right angles to the axis and brought out between two of the turns The parts of the wire are insulated by being kept at a distance from each other The ends of the wire are carried for a short distance at right angles to the axis of the helix, they are then bent round into such a form that they may be placed in two cups of mercury which are supported one vertically above the other on horizontal metallic arms The solenoid can thus be suspended with its axis horizontal, and can turn round the vertical axis, passing through the mercury cups It is called right-handed when the turns appear to go in the direction of the hands of a watch, left-handed when in the opposite direction The effect of the solenoid when a current is passing through it is precisely the same as that of a series of parallel circular currents at right angles to its axis When a solenoid is traversed by a current, it has all the properties of a magnet in which the south pole is that in which, to an observer looking on it, the current appears to move in the direction of the hands of a watch This follows from what we have just stated with regard to the action of the earth on a closed current in a vertical plane Let this solenoid be suspended in its mercury cups, the terminals of the battery being attached to the arms which carry them, and let it be placed with its axis not in the direction of the magnetic meridian, it will immediately begin to move so as to place itself in that plane, and after a few oscillations will set itself in it just as a magnet would If it be removed from its position by the hand, it again returns to it It will be found, also, that when in its position of rest the currents in the spirals are descending to the east of the axis of suspension and ascending to the west of it It appears, therefore, that the south pole of the solenoid is that in which an observer to the south of it sees the currents circulate in the direction of the hands of a watch This experiment may also be shown by constructing a very small solenoid and attaching it to the terminal wires of De la Rive's floating battery Again, a magnet and a solenoid act upon each other just as a magnet would act upon a magnet

When the north pole of one is brought near to the south pole of the other, attraction takes place, while if the two north poles or the two south poles are presented to each other, repulsion is exhibited. The solenoid may even be made to attract iron filings, and in every respect the law of attraction and repulsion between a magnet and a solenoid is plainly the same as that which would hold between the magnet and a second magnet whose strength is the same as that of the solenoid. Lastly, one solenoid acts upon another as one magnet acts on another magnet, and if a solenoid, capable of turning about an axis, is brought near to a rectilinear current, it takes a set according to the same laws which Œrsted gave for the action of a current upon a magnet. But these actions of a solenoid on a solenoid and of a current on a solenoid can all be brought under the laws of the action of one current upon another. Hence Ampère was led to his celebrated theory of magnetism, in which he assumes the existence of currents around the magnet in places perpendicular to the magnetic axis. He supposes that around the molecules of a magnet currents are perpetually circulating in a direction at right angles to the magnetic axis, and such that an observer at the south pole of the magnet would see them moving in the same way as the hands of a watch; within the magnet these currents neutralise one the effect of the other, but at the outside of the magnet the aggregate effect of the whole is that of currents circulating round the magnet in the direction just indicated.

ELECTROLYSIS (λύω, to loosen or disengage), is the resolving or splitting up of a compound into its elements by means of an electric current. A few weeks after the invention of the pile by Volta, Nicholson and Carlisle showed by means of it the separation of water into its constituent elements, oxygen and hydrogen, and not many years elapsed before Davy displayed at the Royal Institution potash resolved by the battery into oxygen and potassium. Then followed quickly the discovery and preparation of new metals, and the invention of the electrotyping and electro-plating processes, and there is now no more important application of electricity to the arts than that which depends upon electro chemical decomposition.

Let the wires connected with the poles of a battery of three or four cells be terminated by slips of platinum, and let these be immersed in water, slightly acidulated with sulphuric acid, it will be found that they immediately become covered with bubbles of gas, which increase and soon begin to rise through the liquid. If the gases are collected with proper precautions it will be found that one of them is pure oxygen, and the other pure hydrogen, and that the amounts of them are one volume of oxygen to two of hydrogen, the same quantities, in fact, as those in which oxygen and hydrogen are associated to form water. It will always be found, too, that the oxygen is given off at the side connected with the positive or platinum pole of the battery, the hydrogen at that connected with the negative or zinc pole.

Our nomenclature, and much of our knowledge on this subject, we owe to Faraday. He calls any body which undergoes decomposition (similar to that which we have described in the case of water) an *electrolyte*, the surfaces at which the current enters or leaves an electrolyte he calls *electrodes* (ὁδός, a way), calling that the *anode* (ἀνα, upward) at which it enters, and that at which it leaves the *kathode* (κατα, downward). (See *Anode*.) The electrolyte, under the influence of the current, is split up into two portions called *ions* (ἰόν, that which goes), which move towards the two electrodes, that which goes to the anode is called the *anion*, the other the *kathion*, going as it does to the kathode. With these definitions we proceed to the laws of electrolysis.

1. *Electrolysis only takes place when the electrolyte is in the liquid state.* For during electrolysis a species of discharge takes place which is very different from ordinary conduction in a solid. It includes, if it does not wholly depend on, a convective action, during which the parts of the body under electrolysis are transferred, one to one side, the other to the other, and it requires the free mobility of particles afforded by the liquid form. This transference of particles may be well shown in the following way. Let two vessels containing solution of sulphate of sodium be placed side by side, and connected by means of a siphon filled with the same liquid, and let a slip of platinum connected with the positive pole of a battery be placed in one, and a slip connected with the negative pole be placed in the other. The sulphate of sodium (Na_2SO_4) is divided into two portions, the metal (Na_2) goes towards the negative pole, and the acid radical, as it is called, (SO_4) goes to the positive pole, and it is found, after a time, that the whole of the metal is in one vessel, the whole of the acid radical in the other. If the electrolyte is solidified, this action is at once put an end to, and the current, as may be seen by including a galvanometer in the circuit, immediately ceases. This can be shown by plunging into ice cold water an electrode which has been chilled in a freezing mixture, an excessively thin film of ice covers the surface, but this is quite sufficient to prevent electrolytic action, when the ice melts the current passes, and the decomposition at once begins. In the case of gases there are some cases in which decomposition of a compound gas takes place under the influence of electric discharge, but such action is not at all of the nature of electrolysis.

2 *During electrolysis the components of the electrolyte are resolved into two groups, one of which goes to the positive electrode or anode, the other to the negative electrode or kathode* This law has been already illustrated, under it elements, when in combination, are divided into classes and called *electro-positive* or *electro-negative*, those which go to the negative electrode being electro-positive, and those which go to the other electro-negative, these names having reference to a theory which supposes them to contain respectively positive and negative electricity, which is the cause of their attraction to the electrodes, and which they neutralise with the negative and positive electricity with which the electrodes are kept charged by the pile According to this division hydrogen and all the metals are electro-positive, during electrolytic decomposition they all appear at the kathode, while oxygen, and all the bodies that resemble it, are electro negative, and appear at the anode In salts also, which are not binary compounds, such as nitrate of potassium (KNO_3), or sulphate of copper ($CuSO_4$), the metallic portion of the salt goes to the kathode, and all the rest of the elements (NO_3 or SO_4) go to the anode This division of course corresponds with Faraday's division into kathions and anions, he gave them these names in order to be free of all hypothesis, but the words electro positive and electro negative are still commonly used, even by those who do not admit the theory which gave rise to them

3 *The electrolytic action of the current is the same at all parts of the circuit* If several decomposing cells are placed in the same circuit at different parts, each filled with acidulated water, or with any other electrolyte, it is found that precisely the same amount of decomposition occurs in each

4 *The quantity of the electrolyte decomposed in a given time is in simple proportion to the strength of the current, and the same quantity of electricity decomposes chemically equivalent quantities of different electrolytes* Suppose that in the same circuit are included a tangent galvanometer (see *Galvanometer*) and a decomposing cell, and that, a current passing, a certain amount of gas is collected from the decomposing cell in one minute Then if the strength of the current be increased till the galvanometer indicates that it is doubled, twice the quantity of gas will now be given off per minute From the perfectly definite character of this action, Faraday proposed to use it as a means of measuring the strength of the current, and hence came his *Voltameter* It consists of a bottle into which platinum wires carrying platinum plates project through the stopper A tube of glass passes through the stopper and bends downwards outside after the manner of an ordinary delivering tube for gases With the exception of the tubular opening the bottle is completely closed, and it contains water acidulated with dilute sulphuric acid The current passing, electrolysis of the water takes place, the mixed gases are given off, and by means of the glass tube are collected, according to the ordinary way for collecting gases in a graduated jar The strength of the current is measured by the quantity of gas given off in a certain time The second part of this law may be illustrated by placing in the same circuit a number of decomposing cells containing different electrolytes, for example, water, solution of sulphate of copper, fused chloride of tin, and permitting the current to pass through them all at once The quantity of electricity that passes must be the same for each, and on collecting the products of decomposition with proper precautions it will be found that the quantities of the electrolytes decomposed are strictly in proportion to their chemical equivalents Moreover, if the amount of chemical action which has gone on within the battery is determined, there being of course no local action on the plates, it will be found that it also bears the same relation to the decompositions in the various cells as they do among themselves Thus, supposing the battery to consist of zinc and platinum with some exciting liquid, for every 32 7 grains of zinc dissolved in the battery cells 9 grains of water are decomposed in the voltameter into 1 grain of hydrogen and 8 of oxygen, in the sulphate of copper cell 31 7 grains of copper are thrown down, and a corresponding quantity of the acid radical liberated, and in the cell containing chloride of tin, 59 grains of tin and 35 5 of chlorine are set free, these numbers being those which represent chemically equivalent quantities of the respective bodies, that is, quantities which may be substituted for each other in forming chemical compounds Suppose again, that the voltameters are placed side by side in such a manner that the current dividing itself passes part through one and part through the other, then whether the voltameters contain the same electrolyte or not the total quantity of decomposition that goes on in the two is chemically equivalent to that which goes on in a voltameter arranged in the same circuit, so that the whole of the current may pass through it

In the case of electrolysing such bodies as sulphate of sodium the results obtained are very much complicated by what is called *secondary action* It is found that not only is there an equivalent of sulphate of sodium decomposed, but that oxygen is besides given off at the positive electrode and hydrogen at the negative The current thus appears at first sight to do double work in decomposing both water and sulphate of sodium. This is, however, a result of purely

chemical action. As we have said, at one pole there is liberated sodium (Na_2), and at the other the acid radical (SO_4), or as it used to be called *oxysulphion*. The sodium attacks at the moment of its liberation the water in which the salt has been dissolved according to a chemical reaction expressed by the symbols—

$$Na_2 + 2H_2O = 2NaHO + H_2,$$

and thus caustic soda is formed, and hydrogen set free, which bubbles up, and as will be remarked, appears in equivalent quantity Similarly, in the other case, the group of atoms SO_4 coming in contact with a molecule of water breaks up and at the same time forms sulphuric acid, and gives off oxygen Thus—

$$SO_4 + H_2O = H_2SO_4 + O$$

In almost all cases of electrolytic action, except where the electrolyte is a binary compound in the fused, not dissolved, state, secondary action is an accompaniment, and it is frequently difficult to separate the effects due to one from those due to the other cause The decomposition of water in the voltameter is by many authorities, and with very good reason, ascribed to secondary action It is held that water alone is not an electrolyte, if pure water be submitted to the action of the battery, little or no decomposition occurs even though a large number of cells be used, but on acidulating it with a little sulphuric acid, electrolysis at once sets in The reason given is this the sulphuric acid H_2SO_4 breaks up into two portions, of which one H_2 goes to the kathode, and rises there in bubbles The other SO_4 is set free at the anode, and there acting on the contiguous molecules of water combines to reform sulphuric acid and liberate the oxygen Oxygen and hydrogen are thus set free in the proportion in which they form water, the action depending on the decomposition of the sulphuric acid by the pile, and sulphuric acid, being constantly reformed, there is no loss of it in the voltameter Distilled water is, it is true, decomposed to some extent by a powerful battery, but Davy, during a series of experiments with a somewhat different object, found it almost impossible to obtain pure water even with the most extraordinary precautions He operated in vessels of marble and of glass, and found the marble and glass slightly dissolved by the water, in vessels of gold and of wax, but even there the water was contaminated by absorbing impurities from the air, and as he approached complete purity the amount of electrolytic decomposition became excessively small

When several electrolytes are mixed, the results of electrolysis depend upon the strength of the current, and on the qualities of each in the mixture A strong current generally acts somewhat on all of them, and gives at one pole a mixture of the anions, at the other a mixture of the kathions, and the quantity in which the several elementary bodies appear depends upon the quantities of the compounds in the mixture, and on the relative ease or difficulty with which they yield to decomposition When the current is weak only that which yields easiest is, in general, electrolysed. The Becquerels and Matteucci applied themselves to the investigation of this question, as did also Daniell and Miller, but the quantitative laws cannot yet be said to be at all thoroughly understood

There are many points concerned with electrolytic action which our limits force us to leave almost untouched We refer the reader for fuller information to De la Rive's Treatise, (vol ii, in particular) Faraday displayed the electrolytic decomposition due to frictional electricity, and likewise investigated the laws of electrolysis by the galvanic current (See *Exp Researches*, vol i, or Phil. Trans See also the Papers of Grove and Graham, and a paper by Andrews, *An de Chem et de Phys* (N S) t L, on the Electrolytic Decomposition of Water by the Electric Machine

ELECTROLYTE Any compound substance which undergoes decomposition or separation into its constituent parts, under the influence of the electric current, is called by Faraday an *electrolyte* Electrolytes are all chemical compounds, and all, so far as we know at present, contain a metal and a non-metal, or something chemically equivalent to each of them No success has yet attended endeavours to decompose such bodies as definite alloys or amalgams Electrolytes must always be in the liquid condition, whether brought to it by fusion, or by solution in some liquid In this condition they must be capable of transmitting the electric current (See *Electrolysis*)

ELECTRO-MAGNET An electro-magnet is formed by wrapping round a core of soft iron a good many turns of moderately thick and well-insulated copper wire The core is generally bent into the form of a horse shoe It is frequently made by screwing the ends of two soft iron cylinders to a stout flat iron bar It must be formed of very pure iron, and be made perfectly soft by the most careful annealing after the bending, if it is bent, has taken place. It is polished with a file, the greatest care being taken to avoid twisting it If this be not done, the bar retains a portion of its magnetism after the current ceases The wire is moderately thick and insulated with silk or cotton and is coiled chiefly about the two extremities,

and in such a way that, to an observer looking upon the poles, it appears to be wound in opposite directions upon them On sending a current through the coil, the core becomes instantaneously a magnet, and on breaking contact with the battery, it loses its magnetism at once The power of the electro-magnet is enormously greater than that of any permanent magnet A permanent magnet, weighing 1 pound, has been made to carry 27, but Dr Joule was able to construct a small electro-magnet, by arranging the coils to advantage, and proportioning the wire of the core, and the thickness and length of the wire, which would carry 3500 times its own weight The following are the laws connected with electro-magnets, Muller has investigated them The temporary *magnetic moment* depends upon the strength of the current, and on the number of turns of the wire, and also on the length and diameter of the soft iron core There is a limit, however, in the case of a thin iron core, to the advantage gained by putting on a large number of turns in the spiral, and even with a thick bar, more may be lost by increasing the number of turns, from the resistance offered to the current and consequent diminution of it, than there is gained by multiplying the number of coils *The magnetic moment is proportional to the strength of the current, if it be not very great, to the number of turns in the spiral within the limits just mentioned, and to the square root of the diameter of the core* It is found also that the magnetism is the same whether the core be an iron bar, or a hollow iron cylinder of the same diameter

ELECTRO-MAGNETIC MACHINE See *Magneto-Electric Machine*, and *Electro-Magnet*

ELECTRO-MAGNETISM A name sometimes applied to that part of the science of electricity and magnetism which treats of the production and properties of temporary magnetism by the passage of a current of electricity round a bar of soft iron The division is useless For information on the subject, see *Magnetism*, *Electro-Magnet*

ELECTROMETER An instrument for measuring differences* of electric potential between two conductors through effects of electrostatic force

The word electrometer is frequently applied to that which we have called in this work an electroscope, which is merely an instrument for indicating a difference of potentials without attempt at measurement (See *Electroscope*, *Bohnenberger's Electrometer*, &c)

Besides the torsion balance of Coulomb which we have described, (see *Balance*, *Torsion*,) the principal electrometers are that of Peltier, and those invented by Sir William Thomson, who has devoted much time and labour to the construction of them A description of these instruments would require many pages, all that we can do here, is to give a very brief indication of the nature of them, and to refer the reader to detailed works on electricity, and to the report referred to in the note below, in which the fullest information, with diagrams and descriptions, will be found

Peltier's Electrometer is constructed in the following way A horizontal bar of brass tipped with a knob at each end, is carried on a carefully insulating support This bar is connected with a brass rod, which rises vertically, and is furnished with a large ball at the top A charge being communicated to the ball at the top spreads itself over the whole brass rod, and over the horizontal bar below Upon a vertical pivot, at the centre of the horizontal bar, a very light wire of aluminium swings horizontally The wire is bent into such a form that, though the centre of it is raised upon the pivot, nearly all the rest of it lies in the same horizontal plane with the bar of brass, and when the instrument is uncharged, the aluminium wire is in contact with the brass bar through the greater part of its length It is kept in this position by a small magnet attached to the swinging wire, and the instrument, when in use, is placed so that the brass bar may be in the magnetic meridian When a charge is given to the instrument, the brass bar is as we have said electrified, so also is the aluminium wire by contact Repulsion takes place between the two, and the wire, compelled towards the magnetic meridian by the magnetic couple acting upon it, takes a position depending upon the strength of the charge. The angle which it has turned through is read off on a divided circle placed below it

There are three principal forms of electrometer invented by Sir W Thomson He has called them the Absolute Electrometer, the Quadrant Electrometer, and the Portable Electrometer

The Absolute Electrometer consists essentially of two parallel circular plates attracting one

* Difference of electric potential is that which produces electromotive force, and electromotive force tends to produce a flow of electricity between two points which have a difference of electric potential The words "through effects of electrostatic force," distinguish between electrometers and galvanometers, which latter measure differences of electric potential by means of electrodynamic effects (See *Electromotive Force Electrostatics*, *Electrodynamics*) The definition in the text is quoted from the report of Sir William Thomson on Electrometers and Electrostatic Measurement Report to the British Association for the Advancement of Science, on Standards of Electric Resistance, 1867.

another One of them, the upper one, is suspended from one arm of a balance, the other is capable of being moved to a greater or less distance from the first by means of a micrometer screw The upper disc is always brought to a fixed position (which can be very accurately determined) by means of the attraction of the lower, the amount of attraction being regulated by the distance between the two plates It is thus seen that the electric force is actually weighed, and Sir W Thomson has given formulas by means of which the difference of potentials is deducible in absolute measure, the areas of the plates and the distance between them being known

In the *Quadrant Electrometer* a thin aluminium "needle" (or rather elongated plate) is supported by a bifilar suspension in a horizontal position It is electrically connected with the interior coating of a Leyden jar, which forms part of the instrument, and arrangements are made, by means of a replenisher,* for keeping the charge of the jar constant The "needle" swings inside a cylindrical box which has been divided into four quadrants, and has circular apertures at the top and bottom, through which the suspension of the needle and a weight attached to its centre pass The opposite pairs of quadrants are connected together by means of wires, but each quadrant is insulated from those adjacent to it By means of "electrodes," or wires which proceed one from each of the pairs of quadrants, a charge can be communicated to one or other of the pairs In this case the needle, which, we have already mentioned, is kept electrified, swings round the axis of suspension to one side or the other, the bifilar suspension acting against this tendency to turn, and causing it to take up a position depending upon the amount of charge that has been given to the quadrants To measure the angle through which the needle has turned, the same arrangement is made use of as that which is adopted in the case of the *mirror galvanometer* A small mirror is attached to the needle and turns with it In front of the instrument is placed a horizontal scale with a slit or hole in the middle of it A lamp which is set behind this slit sends a beam of light to the mirror, and the light reflected falls upon the scale By reading off the division of the scale on which the reflected beam falls, the angle through which the mirror and needle have turned is determined

The Portable Electrometer In this instrument there are two parallel discs of brass, the lower of which is permanently connected with the inside coating of a Leyden jar, and the other, which is insulated from everything except a wire which proceeds to the outside of the instrument, and by means of which a charge can be given to the disc In the middle of the lower disc there is a square hole cut, in which a square aluminium plate, much on the principle of a cart-weighing machine, is suspended, except that, instead of levers and weights, the torsion of a tightly stretched platinum wire keeps the plate in position An index arm proceeds out to the circumference of the disc, and with the aid of a lens it is possible to determine with great accuracy when the index is in its proper place On giving a charge to the upper plate, attraction or repulsion takes place between it and the lower, the aluminium plate is drawn up or forced down, and the index arm exhibits the motion The upper plate is then moved by means of a screw to a greater or less distance from the other till the index has returned to position The distance between the plates is read off on a scale attached

ELECTRO-METALLURGY is divided into two branches—*Electrotyping*, which is employed in producing copies of medals, coins, seals, &c, and *Electroplating*, which is the art of covering baser metals with a thin coating of silver or gold by means of electricity

ELECTROMOTIVE FORCE is the force by which electricity is put in motion, or, in other words, the force which causes a transfer of electricity between two points is called the electromotive force between those points According to Ohm's law, the strength of an electric current, which is measured by the quantity of electricity that flows through any section of the circuit in a unit of time, is directly proportional to the electromotive force, and inversely proportional to the resistance Thus, if the resistance be kept constant, double the electromotive force will produce twice the current, will effect twice as much electrolytic decomposition in a given time (see *Electrolysis*), produce twice as much heat (see *Current, Heating Effects of*), or give twice as great electro-dynamic effect (see *Electro-dynamics, Electro-magnet*), will, in fact, do twice as much work

A current cannot exist without doing work, and the doing of work pre supposes force, hence the origin of the term

The reader may consult *Ohm's Law*, and for full information as to the connection between electricity and work a "Treatise," by Professor J Clerk Maxwell and Professor F Jenkin, "On the Elementary Relations between Electrical Measurements," British Association Report, 1863, and the papers of Sir W. Thomson in the Philosophical Magazine, particularly December 1851

ELECTROMOTOR (*Moveo*, to move) Any arrangement which gives rise to an electric

* A very small electrostatic induction electric machine which is attached to each instrument

current, such as a single cell, a galvanic battery, or a thermo-electric pile is called an *electro-motor*, and sometimes a *rheomotor*.

ELECTRO-NEGATIVE, opposite of *Electro-positive*, which see

ELECTROPHORUS (φέρω, to bear) An instrument for obtaining electricity by means of induction A shallow brass or tin tray, called the form, of convenient dimensions, is filled with a compound of equal parts of shell-lac, resin, and Venetian turpentine The ingredients are melted together and poured into the form, making a cake three quarters of an inch thick A brass plate with well rounded edges is made to cover the resinous plate very nearly, but without approaching too closely the edges of the form It is furnished with a glass handle, which stands vertically from the middle of the plate, and by means of which it can be lifted from place to place To obtain electricity by means of the electrophorus the resinous plate is warmed, and briskly struck and rubbed with a warm, dry cat-skin or flannel It thus becomes negatively electrified The brass plate is then laid upon the resinous plate Owing to its rigidity, it only touches the resinous plate in a few points These become negatively electrified by contact, and if we raised the plate we should obtain a slight negative charge By far the greater part of the plate, however, is acted upon inductively across the thin layer of air lying between it and the resinous plate Positive electricity is attracted towards the resinous plate and negative electricity set free On bringing the finger up to touch the plate, therefore, a spark will be perceived, and the negative electricity escapes, according to the common language on the subject, to the ground The finger is now removed, and the plate raised by means of the insulating handle, when it is found to contain a charge of positive electricity For many purposes the electrophorus is a very convenient instrument In dry weather the charge upon the resinous plate may, and often does, last for weeks

ELECTRO PHOTOMETER, MASSON'S This photometer is described in Watt's *Dictionary of Chemistry*, vol. iii, page 597 It consists of a circular disc divided into white and black sectors of equal size, and set in motion by clockwork at a uniform rate of 250 to 300 revolutions in a second If it be then illuminated by a constant source of light, such as a lamp, it appears of a uniform gray tint, in consequence of the duration of the visual impression on the eye, but if it be illuminated by a practically instantaneous light, such as the electric spark, the black and white sectors become distinctly visible, and appear as if they were fixed, because they have not time to move through a sensible angle in the extremely short interval during which the spark continues If, now, the intensity of the light afforded by the spark be gradually diminished, by removing it to a greater distance, the source of constant light remaining as before, the increase of illumination which the spark affords to the disc ultimately becomes too feeble to render the sectors visible, so that the disc still continues to exhibit a uniform gray tint The relative intensities of the constant and instantaneous lights at which this limit is attained, evidently depend upon the number of the sectors and the velocity of revolution The relative intensities of two electric sparks are as the squares of the distances to which they must be removed from the disc to cause the sectors to disappear, while the disc is illuminated by a constant light On the other hand, to use the instrument for comparing the intensities of two continuous lights, a succession of electric sparks is made to pass in front of the disc, and one of the constant lights is made to approach it till the sectors cease to be distinguishable The same experiment being then repeated with the other light, the intensities of the two are as the squares of the distances thus determined (See *Photometer*)

ELECTROPLATE In electroplating, articles formed of the baser metals are covered with a coating of gold or silver electro-chemically deposited The process is difficult in practice, and requires, in order to be successfully carried on, minute attention to details We give here a general account of it, and of the principle on which it depends, which is very simple, referring the reader for particulars to complete works on the subject First, with regard to the principle When a plate of copper, or silver, or gold, &c, is attached to the positive pole of a battery and immersed in a chemical solution of the same metal, such as sulphate of copper, cyanide of silver, &c, any conducting material attached to the other pole and placed opposite the first in the same solution very soon becomes coated with the metal used The metal plate is gradually eaten away, and an equal quantity of the metal is deposited upon the body at the negative pole This is the foundation of the process. We shall describe electro-silvering The articles to be silvered must first be most carefully cleaned, they are generally made of brass, copper, or German silver, the last being preferable to either of the others When they are made of iron, zinc, or lead, it is necessary to electroplate them with copper, since the silver coating does not adhere to these metals properly They are first boiled in solution of caustic potash by means of which all grease is dissolved, and the surface made uniformly conducting, to remove all traces of oxide they are next washed with dilute nitric acid, and they are finally scoured with fine sand. After this they are coated with mercury by immersion in solution of nitrate of mercury,

the film of mercury thus obtained produces perfect adherence of the silver to the surface. The silvering solution consists of one part of cyanide of silver dissolved in a solution of ten parts of cyanide of potassium to one hundred of water, and is placed in a suitable trough in which the articles to be silvered hang by means of wires from bars of copper stretching across the trough. These bars are connected with the negative or zinc pole of the battery, and a plate of silver attached to the other pole is placed in the bath. The current is immediately set up, and silver from the cyanide is deposited at the negative electrode; the cyanogen, which is set free at the positive electrode, attacks the silver plate and dissolves it, thus keeping the strength of the solution constant. The thickness of the coat depends upon the length of time during which the action is allowed to proceed. The articles on being taken out of the solution and dried present a dull whitish appearance; they are first polished by means of a revolving brush, and afterwards burnished. Electro-gilding is performed in precisely the same way. The solution used consists of 100 water, 10 cyanide of potassium, and 1 cyanide of gold, and it is kept hot during the process. When different shades of gold are required, plates of gold alloyed with silver or copper are employed. For platinising, too, the same method is employed.

ELECTRO POSITIVE AND ELECTRO-NEGATIVE. Elements are called electro-positive, or electro-negative, *with regard to each other*, in any combination, according as they tend to go during electrolysis, respectively, to the negative or positive electrode in the decomposing cell. (See *Electrolysis*.) Thus a list may be formed in which any body, at the beginning, is electro positive with regard to any body which precedes it, and electro-negative with regard to any body which succeeds it; that is to say, if any two of the elements be combined together, and then submitted to electrolytic decomposition, the element nearest the top of the list will go to the positive electrode, or that connected with the platinum plate of the battery. The other will go to the negative electrode, or that connected with the zinc of the battery. The following list by Berzelius is extracted from Miller's Elements of Chemistry, vol. i., but he remarks with respect to it, that probably it is not strictly correct, at least in the case of hydrogen and aluminium; and also that the order may to a certain extent alter with circumstances:—

Electro-negative—

Oxygen	Molybdenum.	Palladium	Zinc.
Sulphur	Tungsten	Mercury	Manganese.
Selenium.	Boron	Silver	Uranium
Nitrogen	Carbon	Copper	Aluminium.
Fluorine	Antimony.	Bismuth	Magnesium.
Chlorine	Tellurium.	Tin	Calcium
Bromine	Titanium.	Lead	Strontium.
Iodine	Silicon	Cadmium.	Barium
Phosphorus.	Hydrogen.	Cobalt	Lithium.
Arsenicum	Gold	Nickel.	Sodium
Chromium	Platinum.	Iron.	Potassium
Vanadium.			

Electro-positive

See also *Grotthus's Hypothesis*.

Under *Affinity* and *Chemistry* was noticed that force, in virtue of which elementary bodies unite to form compounds. Long before the discovery of the pile of Volta, an intimate relation was all but proved to exist between electrical forces and affinity. After that great discovery, Davy established the relationship by many striking proofs. Grotthus, also, in 1805, referred to Volta's pile as "an electrical magnet of which each element, that is, each pair of plates, has a positive and a negative pole. May not a similar polarity come into play between the elementary particles of water when acted upon by the same electrical agent?" As the idea became developed, a connection of polarities was established in crystalline and optical phenomena. Thus, in reference to the formation of crystals, Berzelius, in 1820, wrote: "It is demonstrated, that the regular forms of bodies presuppose an effort of their atoms to touch each other by preference in certain points; that is, they are founded upon a *polarity* which can be no other than an electric or magnetic polarity." In the application of this idea to affinity, the chemical elements were supposed to consist of particles having poles, like poles repelling, unlike attracting each other. (See *Magnet*.) Two bodies with opposite properties, such as an acid and an alkali unite with energy and produce a neutral compound, just as positive electricity unites with negative and produces equilibrium.

But the idea of polarity, as applied to chemical affinity, implies something more than the

repulsion of like poles, and the attraction of unlike Faraday, pursuing with his usual originality and perseverance the track opened up by Davy, was satisfied as to the polar nature of affinity, but saw many difficulties in carrying out the idea of particles endowed with poles According to him, chemical synthesis and analysis must take place by virtue of equal and opposite forces, by which the particles are united or separated "These forces, by the very circumstance of their being polar, may be transferred from point to point For, if we conceive a string of particles, and if the positive force of the first particle be liberated and brought into action, its negative force must also be set free This negative force neutralises the positive force of the next particle, and therefore the negative force of this particle (before employed in neutralising its positive force) is set free This is, in the same way, transferred to the next particle, and so on And thus we have a positive active force at one extremity of a line of particles, corresponding to a negative force at the other extremity, all the intermediate particles reciprocally neutralising each other's action" This view of chemical action reduced to its simplest terms is "an axis of power, having contrary forces exactly equal in opposite directions (See *Electrolysis*, *Polarity*)

ELECTROSCOPE (σκοπέω, to look) An instrument for observing or detecting the existence of free electricity, and in general for determining its kind All electroscopes depend for their action on the elementary law of electric forces, that bodies similarly charged repel each other, bodies dissimilarly charged attract The common electric pendulum may be used as an electroscope, but for most purposes it is not sufficiently delicate

The earliest electroscope, properly so-called, consists of a pair of short pieces of straw suspended by means of silk threads When not in use, the pieces of straw hang down touching each other On touching them with an electrified body, they become excited and stand apart, and this gives us a test for electricity The use of the diverging straws is, however, quite superseded by the gold leaf electroscope which was introduced by Bennet, in 1789

Bennet's Gold Leaf Electroscope A glass shade, with a wide mouth at the top, is placed on a convenient wooden stand The mouth is closed by a wooden stopper, which can, if necessary, be taken out and put in again without trouble Through the centre of the wooden stopper passes vertically a tube of glass, generally varnished with sealing wax or shell lac to improve its insulating properties, and a vertical metallic rod is fixed in the centre of the glass tube by means of silk thread which is rolled round the rod and acts as a packing to keep it in its place The lower end of the rod terminates in a small flat plate, to the sides of which two narrow strips of gold leaf are attached, and are thus suspended opposite each other The upper end of the metallic rod is furnished either with a circular horizontal plate or with a brass knob A small dish of chloride of calcium or of quick-lime, ought to be placed inside the glass shade, the air will thus be kept dry, and the insulation of the instrument very much improved

If an electrified body be brought near to the top of the instrument, induction takes place, the top becomes electrified oppositely to the body presented, and the gold leaves similarly They, both possessing the same kind of electricity, repel each other, and diverge more or less in proportion to the strength of the charge, and to the nearness of the electrified body We are thus enabled to detect the presence of free electricity To examine the nature of the electricity, with which a body is charged, we touch with the finger the top plate of the electroscope while it is under the influence of the electrified body, then removing the finger and carrying the electrified body away, we find the gold-leaves remain divergent, being permanently charged, and we know, from the laws of induction, that they possess the opposite kind of electricity to that presented An electrified glass rod, which is positive, and stick of sealing wax, which is negative, are now successively brought near to the top plate, one of them will make the leaves diverge more, and the other will diminish the divergence For that which contains electricity similar to theirs, by induction, increases their charge, and that which contains the opposite kind, by induction, diminishes their charge Knowing, in this way, the kind of electrification of the gold-leaves, we know also the kind of electrification of the body which we were required to test Sometimes the gold-leaf electroscope is furnished with a scale placed behind the gold leaves, in order to measure the angle of divergence of the leaves, and hence infer the amount of charge Such an arrangement is, however, of little use The electroscope cannot be used as an electrometer

The Single Gold-Leaf Electroscope is employed, in some cases, to indicate slight charges A metal rod, arranged exactly as in the last, carries a single fine gold leaf, which hangs between two vertical plates, either of metal or of gilded wood Two horizontal wires which support these plates, pass through the glass shade of the electroscope, and are thus insulated They are terminated by binding screws to which the terminals of a galvanic battery of two or three cells, may be attached. One of the plates is thus kept electrified positively, and the other negatively. If then a charge of any kind be communicated to the gold-leaf, by means of the

top plate, the gold-leaf will tend to move to one or other side, being attracted by one of the plates, and repelled by the other

Volta's Condensing Electroscope consists of a Bennet's gold leaf electroscope, which has the top plate covered with a thin layer of shell lac varnish' On the top of this is placed a second metallic plate furnished with an insulating handle For fuller description and use, see *Condenser*

Bohnenberger's Electroscope is excessively delicate It is a condensing electroscope having a single gold leaf suspended from the metallic rod At equal distances from the gold leaf, and on opposite sides of it, are placed the opposite poles of two dry piles which stand vertically within the glass shade of the apparatus A charge being given to the gold leaf, it is attracted by one of the poles and repelled by the other, and the greatest sensitiveness is obtained by the arrangement See, for further information, *Bohnenberger's Electrometer*.

ELECTROSTATICS treats of the phenomena occasioned by electricity at rest, and in connection with them of the production and discharge of stationary charges of electricity A large portion of that which is generally included under the head electrostatics in consecutive treatises on electricity will, according to the plan of this work, be found under the following heads —*Electricity*, *Electric Machine*, *Induction*, *Electrostatic*, *Discharge*, *Dissipation*, and others to be indicated throughout this article Here we propose to consider the laws of force depending on electricity at rest, and the laws of electric distribution

Electric Force The general and primary law of electric attraction and repulsion is that similarly electrified bodies repel one another, dissimilarly electrified bodies attract (See *Electricity*) Thus a positively electrified body repels another positively electrified body, but attracts one negatively charged From this law also, and from the laws of electrostatic induction (*q v*) follows the attraction of a neutral body by a body charged either positively or negatively For we know that if an electrified body be brought near to one not electrified, induction takes place, on the side of the latter nearest to the electrified body, the opposite kind of electricity to that possessed by it is developed, and on the remote side an equal amount of the like kind But as we shall see directly, the nearer the bodies the greater the electric force, hence the attraction due to the unlike kinds of electricity near to each other is greater than the repulsion due to the like kind at the greater distance, and on the whole predominates A similar consideration explains attraction taking place between two similarly electrified bodies when brought very near to each other

To the genius and experimental skill of Coulomb, we owe the complete investigation, the discovery, and the statement of the quantitative laws of electric attraction and repulsion The chief apparatus which he employed for his experiments on the subject was his celebrated *Torsion Balance*, a full description of which, as modified by Faraday, who also used it for the same purpose, will be found in a separate article (*Balance, Torsion*) It is sufficient for our present purpose to state that it consists of a horizontal arm of non conducting material, carrying a small gilt ball at one end and a counterpoise at the other, and suspended by a very delicate wire, the torsion of which is the force against which the electric forces are tried Another exactly similar gilt ball, which we shall call the carrier, is capable of being put into a definite position, and the attraction and repulsion between these two balls is compared with the angle of torsion of the vertical wire The carrier ball is charged with electricity and put into its proper position, and the other ball allowed to touch it The electricity from the exact similarity of the two balls divides itself equally between them, repulsion takes place, and the moveable ball swings round, till it assumes a position such that the torsion of the wire which tends to return it to its former place, is exactly equal to the repulsion at that distance between the two balls The distance being then altered, so also is the angle of torsion, and by comparing together the distances and the forces of torsion, or what is the same thing the forces of repulsion, the law of the latter at different distances is obtained To investigate the laws of attraction the moveable ball is charged with a certain kind of electricity, and placed at a known distance from the position of the carrier The carrier is now introduced charged with the opposite kind of electricity, and, attraction taking place, the torsion necessary to return the moveable ball to its initial position is determined The same experiment being tried for different positions of the moveable ball the law is known To determine in what manner the attraction and repulsion depend upon the amount of the charge it is necessary to be able to communicate to the balls charges of a given magnitude, or at least charges obeying some law Coulomb's method of doing this was to have a third ball equal and similar to the other two, and by means of repeated contacts with one or both of them, discharging the third ball each time, to subdivide the charges upon them to any required extent

By means of the apparatus and methods just described, Coulomb arrived at the following beautifully simple laws :—

(1) The force of attraction or repulsion varies with the amounts of electricity upon the balls conjointly

(2) The force of attraction or repulsion varies inversely with the square of the distance between the balls

If then we take as unit quantity of electricity, that quantity which attracts or repels an equal quantity placed at unit distance with unit force,* we obtain a number which expresses the magnitude of the force of attraction or repulsion by multiplying together the numbers which express the quantities of electricity upon the balls and dividing the product by the square of the distance The two laws are therefore expressed by the following simple formula Let F denote the force of attraction or repulsion, let Q, Q′ be the quantities of electricity upon the two balls, and let D be the distance between them, then

$$F = \frac{Q \times Q'}{D^2}.$$

and if to the numbers Q, Q′, the signs (+) and (−) be prefixed according as the electricity upon the respective balls is positive or negative, then the force will be attractive or repulsive, according as the sign of F is negative or positive

The mathematical theory of attraction commenced by Coulomb was attacked and largely extended by Poisson, but the most complete and general investigations were those of Green of Nottingham, 1828 These lay unread and unknown till after the principal theorems had been re-discovered by M Chasles and by Sir William Thomson, both independently, and till they were fortunately after long inquiry brought to light by the latter For information on this subject we refer the reader to the papers of Thomson in the Cambridge and Dublin Mathematical Journal, republished in the Philosophical Magazine, those of Chasles in the Journal de l'Ecole Polytechnique, and to a Treatise on Natural Philosophy, by Thomson and Tait

2 *The Distribution of Electricity* on the surface of a *conductor* we shall now briefly consider In the case of a non-conductor, the distribution is necessarily arbitrary, for, the property of a non-conductor being that it prevents the motion of electricity over its surface, and throughout its mass, (see *Conduction*, *Conductor*, *Electricity*), wherever electricity is placed by any means, in the first instance, there it must remain till it is removed by some external influence On a conductor, however, the electricity is free to move from place to place, and since, as we have seen, any two like portions of electricity repel each other, it will readily be understood, that just as water, whose surface is free to move, arranges itself according to a definite law, being influenced by gravitation, so does a quantity of electricity under the influence of the forces of its different parts

A fundamental law of electric distribution on a conductor is, that the whole of the electricity resides in an excessively thin layer at the external surface, none whatever being found throughout the mass or on interior surfaces of the body Various experiments show this Let a metal globe be suspended by an insulating string, and electrified, and let two metal hemispherical covers, made to fit it and provided with insulating handles, be put over it, enclosing it completely, and touching it On removing the covers it will be found that they are electrified, the electricity having passed from the metal ball to their surfaces, and, farther, not the slightest trace of electricity can be discovered on the ball itself Again, if two exactly equal spheres be taken, one of them made of solid metal, and the other of glass, or other non-conducting material, and covered with the finest gold-leaf, and if one be electrified and touched with the other, the electricity divides itself between them, and no electrostatic test will distinguish between the amount of electricity possessed by the one, and the amount possessed by the other, which shows that the capacity of a spherical surface of the finest gold-leaf is as great as that of a globe of equal diameter, composed of solid metal If an ice-pail be insulated and charged, and then tested by means of Coulomb's *proof plane* (*q v*), which consists of a small disc of metal or gilt paper attached to an insulating handle, it will be found that the electricity is on the external surface of the ice pail, and that no indication can be obtained of the existence of electricity on any internal point Metallic shells of various forms, perforated so as to admit

* In electrical measurements the kinetic or absolute unit of force is always made use of, and it is defined as the force which, acting on unit of mass for unit of time, generates unit of velocity Unit of velocity being "that of a point which describes unit of space in unit of time," it will be seen that the unit of force depends only upon the units of space, mass, and time, which are chosen arbitrarily The unit of space adopted by electricians is the centimetre (0 3937 of an inch), the unit of mass is the gramme (15 43 grains), and the unit of time, the second Thus definitely, unit of force is that force which, acting for one second on a mass of one gramme, generates in it a velocity of one centimetre per second, and unit quantity of electricity is that quantity which placed at a distance of one centimetre from an equal quantity attracts or repels it with unit of force The number 981 4 expresses the force of gravity in terms of the unit we have just explained.

the proof-plane or other testing body, are also used instead of the ice-pail, and with the same result

From these experiments, and many others, which might be mentioned did limits permit, we conclude that, in the case of a charged conductor, the whole of the electricity is distributed in an extremely thin layer at the surface

The slightest examination will show that the distribution of electricity at the surface of a conductor depends upon the form of the surface Thus a cylinder, whose length is considerable compared to its diameter, will be found to have the greater part of its electricity at the two ends and but little in the middle The quantitative determination of the distribution of electricity, from point to point, was undertaken by Coulomb in several cases, and the complete agreement of his experiments with the theoretical results obtained by Poisson form the most beautiful confirmation of the accuracy of the experiments, on the one hand, and of the truth of the laws on which the mathematical theory of electricity is founded, on the other The following was the method which Coulomb made use of The theory of the proof plane shows that when the thin conducting disc is placed upon a conductor, and then removed, it carries away an amount of electricity, which corresponds to what Coulomb calls the *electric density*, at the point at which it is applied, that is, the quantity of electricity, per unit area, at that point In fact, the process of applying the proof plane and carrying it away, is exactly the same as if we could cut out the small portion of the conductor which covers it, and carry it away (See *Proof Plane*) Coulomb applied the proof plane to point after point of the body he was examining, and carrying it each time to the torsion balance determined, by this means, the electric density at each A few of the simpler results obtained by him are here stated Upon an insulated sphere, uninfluenced by want of symmetry of bodies external to it (see *Induction*), equal areas contain equal amounts of electricity at every point Upon an oblate spheroid, or egg shaped body, the electricity is found concentrated towards the poles, and removed from the equator The amount of this concentration depends upon the relative lengths of the axes, and, in the case of a very elongated body, almost all the electricity will be found at the two ends while it will be scarcely discoverable in the middle Again, in a prolate spheroid, or body flattened at the poles, like an orange, the electric density will be greatest at the equator, and least at the poles In a general way it may be stated, that on the parts most remote from the mass of the body, the electricity is most concentrated

The subject of the distribution of electricity is beset with difficulties, both to experimenters and to mathematicians Among the former are, besides Coulomb, Cavendish and Faraday, and among the latter, Poisson, Green, Chasles, Liouville, and Thomson The papers of Coulomb are published in the Histoire de l'Academie, 1788, those of Faraday, in his Experimental Researches (Transactions of the Royal Society from 1837, and afterwards republished) For the mathematical theory, the reader may consult the papers of Thomson in the Philosophical Magazine, and the Cambridge and Dublin Mathematical Journal

ELECTROTYPE By the process of electrotyping, a coating of metal is deposited electrochemically upon a prepared surface, and a copy is thus obtained of such articles as medals, coins, seals, &c It is usual to make these copies in copper, other metals can, however, be deposited in this manner. If a plate of metal or other conducting substance be attached to the negative or zinc pole of a battery, and a plate of copper to the other, and if both be immersed without touching each other in a saturated solution of sulphate of copper, the copper plate is gradually eaten away, and an equivalent quantity of copper is deposited at the other pole on the plate attached to it The current passing through the liquid decomposes the sulphate of copper (see *Electrolysis*) into copper, which is deposited at the negative pole, and sulphion (SO_4) which is set free at the other pole The sulphion then attacks the copper plate which forms the electrode The latter is eaten away, and new sulphate of copper is formed This is the principle on which electrotyping depends

When a medal or other article is to be copied, a cast of it is generally taken in gutta-percha, wax, fusible metal, or some material which gives a sharp impression of the original, and a copper wire is fastened into this form while it is still soft If it be made of wax or gutta-percha the face of it is then carefully brushed over with the finest plumbago till a complete conducting surface is obtained, care being taken to make communication between the surface thus produced and the copper wire The form is then attached to the negative pole of a very weak battery, and the other pole to a plate or a lump of copper, and both are immersed in saturated solution of sulphate of copper A current of electricity passes, and the form is soon perceived to be covered with a thin coating of bright copper, which becomes thicker and thicker as the action goes on When the required thickness has been attained the action is stopped, and it is easy with the point of a knife to separate the copper plate from the mould. A perfect reverse copy even of the minutest details is found on the side of the copper which was next the form.

It is not necessary even to use a separate battery in this process, the plates themselves are now very frequently made to form their own battery The following is the way in which this is done To the mould, prepared as before, is attached by a sufficiently long wire a plate of zinc The mould is put in a vessel containing saturated solution of sulphate of copper, and an extra supply of crystals besides, the zinc plate is placed in a porous vessel within the first vessel, and surrounded with dilute sulphuric acid The sulphuric acid attacks the zinc, and causes, as will readily be understood, a deposition of copper on the mould The principle of the action is precisely that of the Daniell's battery (*q v*)

ELEMENTS In astronomy, the quantities whose determination defines the path of a planet or other celestial body, and enables us to compute the place of such body at any past or future epoch The following table contains the elements of the larger planets, and of the satellites The elements of the asteroids would occupy more space than can be spared in such a work as the present, but the general characteristics of the asteroidal orbits are dealt with under the head *Asteroids*

	Symbol	Distance from the Sun in miles *			Longitude of Perihelion	Annual Variation	Longitude of ascending node	Annual Variation
		Mean	Greatest	Least				
Mercury	☿	35,392,000	42,669,000	28,115,000	75° 7′ 0 0″	+ 5 81″	46°33′ 3 3″	— 10 07″
Venus	♀	66,134,000	66,586,000	65 682,000	129 23 56 0	— 3 24	75 19 4 2	— 20 50
Earth	♁	91,430,000	92,963,000	89,897,000	100 21 40 0	+ 11 24	0 0 0 0	
Mars	♂	139,311,000	152,304,000	126,318,000	333 17 50 5	+ 15 46	48 22 44 8	— 25 22
Asteroids								
Jupiter	♃	475,692,000	498,639,000	452,745,000	11 54 53 1	+ 6 65	98 54 20 5	— 15 90
Saturn	♄	872 137,000	920,973,000	823,301,000	90 6 12 0	+ 19 31	112 21 44 0	— 19 54
Uranus	♅	1,753,869,000	1,835,561,000	1,672,177,000	168 16 45 0	+ 2 28	73 14 14 4	— 36 05
Neptune	♆	2,745,998,000	2,771,190,000	2,720,806,000	17 14 37 3		130 6 51 6	

	Symbol	Mean Distance Earth's as 1	Eccentricity	Sidereal Revolution —in days	Synodical Revolution —in days	Inclination of orbit	Annual Variation	Mean daily motion
Mercury	☿	0 387099	0 205618	87 9693	115 877	7° 0′ 8 2″	+ 0 18	14732 419″
Venus	♀	0 723332	0 006833	224 7008	583 920	3 23 30 8	+ 0 07	5767 6[illegible]
Earth	♁	1 000000	0 016771	365 2564		0 0 0 0		3548 19[illegible]
Mars	♂	1 523691	0 093262	686 9797	779 936	1 51 5 1	— 0 01	1886 518
Asteroids								
Jupiter	♃	5 202798	0 048239	4332 5848	398 867	1 18 40 3	— 0 23	299 1 9
Saturn	♄	9 538852	0 055996	10759 2198	378 090	2 29 28 1	— 0 15	120 4[illegible]
Uranus	♅	19 182639	0 046578	30686 8208	369 656	0 46 29 9	+ 0 03	42 2[illegible]
Neptune	♆	30 036970	0 008720	60126 7200	367 488	1 46 59 0		21 400

All the above elements are for the commencement of the year 1850

	Diameter		Volume Earth's as 1	Mass Earth's as 1	Density Earth's as 1	Light received from sun at	
	Apparent at mean distance from earth	In miles				Perihelion	Aphelion
Sun,	1924 20″	852,908	1252691 000	315,000 000	0 25		
Mercury,	6 90	3,058	0 058	0 065	1 12	10 58	4 59
Venus,	16 94	7,510	0 855	0 885	1 03	1 94	1 91
Earth,		7,912	1 000	1 000	1 00	1 034	0 967
Mars,	6 46	4,363	0 168	0 118	0 70	0 524	0 360
Asteroids,							
Jupiter,	37 91	84,846	1233 205	300 860	0 24	0 0408	0 0336
Saturn,	17 52	70,136	696 685	89 692	0 13	0 0123	0 0099
Uranus,	3 91	33,247	74 199	12 650	0 17	0 0027	0 0025
Neptune,	2 80	37,276	105 575	16 773	0 16	0 0011	0 0011

* These distances and all other elements depending on the distance of the sun are such as result on the assumption that the sun's equatorial horizontal parallax is 8 94″, and are taken from Mr. Dunkin's excellent Appendix to Lardner's Handbook of Astronomy

	Compression	Gravity Earth s as 1	Bodies fall in one second	Time of Rotation upon axis	Inclination of equator to orbit
Sun,	..	27 107	436 287	607h 48m 0s	7°20′ 0″
Mercury,	.	0 432	6 953	24 5 28	
Venus,	..	0 982	15 805	23 21 15	
Earth,	$\frac{1}{299\ 26}$	1 000	16 095	23 56 4	23 27 24
Mars,	$\frac{1}{60}$	0 387	6 229	24 37 23	28 27 0
Asteroids,					
Jupiter,	$\frac{1}{16\ 87}$	2 611	42 024	9 55 26	3 5 30
Saturn,	$\frac{1}{9\ 44}$	1 141	18 364	10 29 17	26 48 40
Uranus,		0 716	11 5 4	9 30	
Neptune,		0 756	12 168		

The vernal equinox of four planets, whose inclination is known, when they are severally in the following heliocentric longitude —

The earth in longitude,	108° 0′ 0″	Jupiter in longitude,	314° 0′ 0″
Mars „	79° 15′ 0″	Saturn „	167° 4′ 5″

Elements of the Moon

Mean distance from the earth in miles	238,800
Mean sidereal revolution in days,	27 321661
Mean synodical revolution in days,	29 530589
Mean longitude, January 1st, 1801,	118° 17′ 8 3″
Mean longitude of perigee, at same date,	266° 10′ 7 5″
Mean longitude of ascending node, at same date,	13° 53′ 17 7″
Mean inclination of orbit,	5° 8′ 47 9″
Mean revolution of nodes in days,	6793 391080
Mean revolution of apogee in days,	3232 575343
Mean eccentricity of orbit,	0 054900708
Mass (earth's as 1),	0 011364
Diameter in miles,	21646
Density (earth's as 1),	0 556
Density (that of water as 1),	3 37
Gravity, or weight of one terrestrial pound,	0 16
Bodies fall in one second, in feet,	2 6
Diameter (earth's as 1),	0 264
Inclination of axis,	1° 30′ 10 8″
Maximum evection,	1° 20′ 29 9″
Maximum variation	35′ 42 0″
Maximum annual equation,	11′ 12 0″
Maximum horizontal parallax,	1° 1′ 24 0″
Mean horizontal parallax,	53′ 48 0″
Greatest apparent diameter,	33′ 31 1″
Mean apparent diameter,	31′ 7 0″
Least apparent diameter,	29′ 21 9″

Elements of Jupiter's Satellites

No	Sidereal Revolution	Distance in Radii of Jupiter	Inclination of orbit to ♃ s equator	Diameter Apparent	Diameter In miles	Mass, that of Jupiter being 1
1	1d 18h 20m	6 05	0′7″	1 02″	2352	0 000017328
2	3 13 4	9 62	1 6	0 91	2099	0 000023235
3.	7 3 43	15 35	5 3	1 49	3436	0 000088497
4	19 16 32	26 99	0 24	1 27	2929	0 000042659

Elements of Saturn's Satellites

No	Sidereal Revolution	Distance in Radii of ♄	Diameter in miles	Eccentricity	Discoverer.
1	0d 22h 37m	3 360	1000	0 06889	Sir W Herschel.
2	1 8 53	4 312			"
3	1 21 18	5 339	500	0 0051	J D Cassini.
4	2 17 41	6 839	500	0 02	"
5	4 12 25	9 552	1200	0 02269	"
6	15 22 41	22 145	3300	0 029223	C Huyghens
7	21 7 7	28		0 115	W Bond and W Lassell
8	79 7 53	64 359	1800		J D Cassini

Elements of Saturn's Rings, January 1, 1865

Longitude of ascending node on ecliptic,	167° 43′ 29″
Inclination,	28° 10′ 22″
Exterior diameter of outer ring in miles,	166,920
Interior diameter of outer ring in miles,	147,670
Exterior diameter of inner ring in miles,	144,310
Interior diameter of inner ring in miles,	109,100
Interior diameter of dark ring,	91,780
Breadth of outer bright ring,	9,625
Breadth of division between rings,	1,680
Breadth of inner bright ring,	17,605
Breadth of dark ring,	8,660
Breadth of system of bright rings,	28,910
Breadth of entire system of rings,	37,570
Space between planet and dark ring,	9,760

These values have been deduced by the present writer from a comparison of the best observations and measurements available for the purpose, and he has made them the basis of calculations respecting the phenomena of the ring as seen by the Saturnians The results of these calculations are embodied in Table XI of "Saturn and its System" Although the above values are not to be regarded as rigidly exact, it is probable that they afford a very close approximation to the true dimensions of the ring system

Elements of Uranus' Satellites.

No	Sidereal Revolution	Distance in Radii of ♅	Maximum Elongation	Discoverer
1	2d 12h 28m	7 44	12″	W Lassell
2	4 3 27	10 37	15	O Struve
3	8 16 55	17 01	33	Sir W Herschel
4	13 11 6	22 75	49	Do

We have no satisfactory elements of other four satellites discovered by Sir W. Herschel, but not seen since his time

Elements of Neptune's Satellite.

Discovered by W Lassell.

Sidereal Revolution	Distance in Radii of Neptune	Maximum Elongation
5d 21h 8m	12 00	18″

ELEMENTS, LIST OF, with principal chemical and physical constants

Name	Derivation of Name	Discoverer	Date of Discovery	Symbol	Atomic weight according to Berzelius	Od'ing	Gerhardt	Stas	Watts	Atomicity (Frankland)	Sp gr	Chlorous or Basylous
Aluminium,	L *alumen*, alum	Wohler	1828	Al	27 43	27 5	13 75		13 75	iv	2 6	B
Antimony,	Gr ἀντί, against, and μόνος, one, or French, *moine*, a monk	Basil Valentine	about 1500	Sb	129 24	120 0	122 0		{ 120 3 / 122 0 }	v	6 7	B
Arsenic,	Gr ἀρσενικόν, potent	Brant also Paracelsus	1733	As	75 32	75 0	75 0		75 0	v	3 7	B
Barium,	Gr βαρύς, heavy	Davy	1808	Ba	68 66	68 5	68 5		68 6	ii	4 0	B
Bismuth,	Ger *Weissmuth*, white matter	Agricola	1529	Bi	213 20	208 0	210 0		210 0	v	9 7	B
Boron,	Borax, from Ar *barage*, to shine	Gay-Lussac, and Thénard	1808	B	21 82	11 0	11 0		11 0	iii	1 47	B
Bromine,	Gr βρῶμος, an offensive odour	Balard	1826	Br	78 39	80 0	80 0	79 750	80 0	i	5 54	C
Cadmium,	Gr καδμεια, calamine	Stromeyer.	1817	Cd	111 66	112 0	56 0		56 0	ii	8 6	B
Cæsium,	L *cæsius*, sky blue	Bunsen.	1861	Cs					133 0	i		B
Calcium,	L *calx*, lime	Davy	1808	Ca	20 51	20 0	20 0		20 0	ii	1 58	B
Carbon,	L *carbo*, coal.	Known to the ancients		C	12 25	12 0	12 0		12 0	iv	3 5	B
Cerium,	The planet Ceres.	Klaproth, and also by Hisinger and Berzelius	1803	Ce	46 05				46 0	vi		B
Chlorine,	Gr χλωρός, green.	Scheele	1774	Cl	35 52	35 5	35 5	35 368	35 5	i	{35 5 (H) / 1 33 (liq.)}	C
Chromium,	Gr χρῶμα, colour	Vauquelin	1797	Cr	56 38	53 5	26 25		26 2	vi	7 3	B
Cobalt,	Ger *Kobold*, an evil spirit	Brandt	1733	Co	29 56	59 0	29 5		29 5	vi	7 7	B
Columbium or Niobium,	*Columbite*, name of mineral	Hatchett	1801	Cb					97 6	iv		B
Copper,	L *Cyprium*, the isle of Cyprus	Known to the ancients		Cu	63 41	63 5	31 75		31 7	ii	8 9	B
Didymium,	Gr δίδυμος twins	Mosander	1841	Di					48 0	ii		B
Erbium,	Ytterby, locality in Sweden	Mosander	1843	Er								B
Fluorine,	Fluor spar, name of mineral	Scheele	1771	Fl	18 73	19 0	19 0		19 0	i		C
Glucinum,	Gr γλυκύς, sweet	Vauquelin	1798	Gl	26 54	4 7			{ 4 7 / 7 0 }	ii	2 1	B

Name	Derivation of Name	Discoverer	Date of Discovery	Symbol	Atomic weight according to Berzelius	Odling	Gerhardt	Stas	Watts	Atomicity (Frankland)	Sp gr	Chlorous or Basylous
Gold,	Probably from Hebrew, signifying to shine	Known to the ancients		Au	199 20	196 5			196 0	iii	12 0	B
Hydrogen,	Gr ὕδωρ, water, and γενναω, to produce	Cavendish and Watt	1781	H	1 0	1 0	1 0	1 0	1 0	i	0 069	B
Indium,	The colour *indigo*	Reich & Richter	1863	In					35 91			
Iodine,	Gr ιοειδής, violet coloured	Courtois	1812	I	126 56	127 0	127 0	126 533	127 0	i	4 95	C
Iridium,	Gr ιρις, rainbow	Tennant	1804	Ir	197 68	198 0	98 5		98 6	vi	22 0	B
Iron,	Probably from Hebrew, signifying to melt	Known to the ancients		Fe	27 18	28 0	28 0		28 0	vi	7 79	B
Lanthanum,	Gr λανθανειν, to lie hid	Mosander	1839	La		47 0			46 0	ii		B
Lead,	Gr μολυβδος, Galena, an ore of lead	Known to the ancients		Pb	103 73	103 5	103 5		103 6	iv	11 4	B
Lithium,	Gr λιθος, a stone	Arfvedson	1817	Li	6 44	7 0	7 0	7 004	6 5 / 7 0	i	0 59	B
Magnesium,	Magnesia, locality in Asia Minor	Davy	1808	Mg	12 69	12 0	12 0		12 0	ii	1 74	B
Manganese,	Mangana, in the East Indies, or from Magnesia	Pott	1740	Mn	27 71	27 0	27 5		27 6	vi	7 0	B
Mercury,	Heathen god	Known to the ancients		Hg	101 43	100 0	100 0		100 0	ii	13 5	B
Molybdenum,	Gr μολύβδαινα, lead ore, galena, because mistaken for lead	Scheele	1778	Mb	47 96	48 0	48 0		46 0 / 48 0	vi	8 6	B
Nickel,	Ger *kupfernickel*, false copper	Cronstedt	1751	Ni	29 62	29 0	29 5		29 0 / 29 5	vi	8 6	B
Nitrogen,	Gr νιτρον, nitre, and γενναω, to produce	Rutherford	1772	N	14 186	14 0	14 0	14 009	14 0	v	0 97	B
Osmium,	Gr οσμη, an odour	Tennant	1804	Os	99 72	99 5			100 0	vi	21 0	B
Oxygen,	Gr ὀξύς, acid, and γενναω, to produce	Priestley	1774	O	8 013	16 0	16 0	15 960	16 0	ii	1 01	C
Palladium,	L Pallas name of ancient deity, Minerva	Wollaston	1803	Pd	53 36	53 0			53 0	iv	11 3	B
Phosphorus,	Gr φως, light, and φερειν, to carry	Brandt	1669	P	31 434	31 0	31 0		31 0	v	2 0	B
Platinum,	Span *platina*, little silver	Wood	1741	Pt	98 84	98 5	98 5		99 0	iv	21 0	B

Name	Derivation of Name	Discoverer	Date of Discovery	Symbol	Atomic weight according to Berzelius	Odling	Gerhardt	Stas	Watts	Atomicity (Frankland)	Sp gr	Chlorous or Basylous
Potassium,	Pot ash from its occurrence in ash of plants	Davy	1807	K	39 25	39 0	9 0	39 04	39 0	i	0 86	B
Rhodium,	Gr ῥόδον, a rose	Wollaston	1804	Rh	52 19	52 0			52 0	vi	11 0	B
Rubidium,	L *Rubidus*, red	Bunsen	1861	Rb					85 4	i	1 52	B
Ruthenium,		Claus		Ru		52 0			52 0	vi	11 4	B
Selenium,	Gr σελήνη, the moon	Berzelius	1817	Se	39 63	80 0	79 5		79 0	vi	4 3	C
Silicon,	Silex flint	Berzelius	1823	Si	22 22	28 5	28 5		28 0	iv	2 49	B
Silver,	Probably from Hebrew, money	Known to the ancients		Ag	108 3	108 0	108 0	107 600	108 0	i	10 4	B
Sodium,	*Salsoda*, name of a plant	Davy	1807	Na	23 31	23 0	23 0	22 98	23 0	i	0 93	B
Strontium,	Strontian, place in Scotland	Davy	1806	Sr	43 85	44 0	43 75		43 8	ii	2 5	B
Sulphur,	L *Sulphurium*, Sanscrit *sulvari*, sulphur	Known to the ancients		S	32 239	32 0	32 0		32 0	vi	2 0	C
Tantalum,	Tantalite, name of mineral	Ekeberg	1802	Ta	184 89	138 0			137 6	iv	10 78	B
Tellurium,	L *Tellus*, the earth	Reichenstein	1782	Te	64 62	128 0	129 0		128 0	vi	6 2	C
Terbium,	Ytterby, locality in Sweden	Mosander	1843	Tr								B
Thallium,	Gr θαλλος, a green twig	Crookes	1861	Tl					203 0	i	11 8	B
Thorinum,	Ancient deity, Thor	Berzelius	1828	Th	67 70	59 5	59 5		59 5	iv	7 7	B
Tin,		Known to the ancients		Sn	58 92	118 0	59 0		{116 0 / 118 0}	iv	7 29	B
Titanium,	Titans mythological deities	Gregor	1791	Ti	24 33	48 5	25 0		50 0	iv	4 3	B
Tungsten,	Swedish, Tungsten, heavy stone	Scheele	1781	W	94 79	92 0	92 0		92 0	vi	17 5	B
Uranium,	Urania, one of the Muses	Klaproth	1789	Ur	217 26	60 0	60 0		60 0	vi	18 4	B
Vanadium,	Vanadis a Scandinavian goddess	Sefstrom	1830	V	68 57	68 5	68 5		68 5	vi		B
Yttrium,	Ytterby, locality in Sweden	Gadolin	1794	Yt	32 25	32 0	32 0		61 7	ii		B
Zinc,	Ger *Zinken*, nails	Paracelsus	doubtful	Zn	32 31	32 5	32 6		32 5	ii	6 9	B
Zirconium,	Ceylonese *zircon*, four-cornered	Klaproth	1789	Zr	33 67	33 5	89 6		{33 5 / 89 5}	iv	4 3	B

ELEMENTS, MAGNETIC See *Magnetic Elements*

ELEMENTS, SPECTRA OF THE When rendered incandescent by the induction spark or in a *Geissler's Tube*, each element gives a spectrum of the second order (Huggins), consisting of coloured lines of light separated from each other by dark intervals These spectra are perfectly definite and invariable when produced under similar circumstances, they may therefore be used as a test for the presence of any element The most complete research on this subject is that of Mr Huggins (see Phil Trans, 1864, page 139). His memoir is accompanied by a very elaborate map (See *Spectra*, *Fraunhofer's Lines*)

ELEVATION In astronomy, the angular height of a celestial body above the horizon The term altitude is more commonly employed, except when the elevation of the pole of the heavens is referred to

ELLIPTICAL POLARISATION See *Circular Polarisation*

ELONGATION (*e*, from, and *longus*, long) The angular distance of a planet from the sun, or of a satellite from its primary, viewed from the earth

EMERSION (*emergo*, to emerge) The reappearance of any celestial body which has been eclipsed or occulted The term is commonly limited to the reappearance of a star after occultation by the moon, and to the reappearance of Jupiter's satellites

EMISSIVE THEORY OF LIGHT See *Corpuscular Theory of Light*

EMERY See *Aluminium*

EMULSIN A white friable opaque substance obtained both from sweet and bitter almonds, and possessing the property of a ferment Under its influence amygdalin is split up into hydride of benzoyl, hydrocyanic acid, and glucose Its composition is not known Emulsin is called *synaptase* by some chemists (See *Almonds*, *Oil of Bitter*, *Amygdalin*)

ENCKE'S COMET A well known comet of short period, the first of the class ever recognised Encke, who established the periodic character of this body's motion, also detected the fact that its successive returns to perihelion are accelerated by a short interval of time from which circumstance he was led to conclude that the comet's motions are retarded (and so its period shortened) by the resistance of an ethereal medium

ENDLESS SCREW A screw fixed so as to be only capable of rotating about its own axis, and associated with a toothed wheel, the axis of which is usually perpendicular to that of the screw The teeth of the wheel are set so as just to agree with the obliquity of the threads of the screw which, as it rotates, takes up the teeth one after another, and so makes the wheel revolve about its axis As the teeth never get to the end of the screw, but keep up a constant succession, the term "endless" has been applied to the contrivance Where the endless screw is turned by a winch handle, and acts on a wheel and axle employed to raise weights like a windlass, the advantage gained is equal to the product of the separate advantages, (1) of the lever (arm of the winch) and the screw, (2) of the wheel and axle (See *Compound Machines*, *Wheel and Axle*, *Screw*) The adjustment screws of optical instruments are usually endless screws

ENERGY (ἐν, within, and ἔργον, work) Inherent power to perform work The term received its scientific meaning, namely, the power of a machine or moving body to do work against some force such as gravity, from Dr Young Energy is of two kinds, kinetic (from κινητος, moving) and potential Kinetic energy is the actual amount of work a moving body is capable of doing at any instant during its motion It may be estimated as soon as the mass and velocity are known A body of given mass, moving with given velocity, must be capable of performing the same amount of work, whatever the direction of motion, and whatever the opposing force Let us suppose the direction to be vertical, and consequently the force against which the work is done to be gravity The body will rise with gradually decreasing speed until its velocity is spent Now the height to which a body started with an initial velocity will rise is found by dividing the square of the velocity by twice the acceleration due to gravity, and the height in feet multiplied by the weight of the body in pounds will give the number of units of work accumulated in the body at starting Hence the kinetic energy of a moving body is measured by the product of the weight in pounds by the square of the velocity divided by twice the acceleration due to gravity

When the moving body reaches the highest point of its course, its kinetic energy is spent The body is not, however, in the same condition as at starting If free to fall to its first position, it will acquire a kinetic energy exactly equal to that which has been expended in raising it Thus the energy of motion has not been lost, but has been converted into an advantage of position This advantage has been aptly termed by Professor Sir W Thomson *Potential Energy* As the kinetic energy of a body diminishes, its potential energy increases, and the sum of the two is therefore constant (See *Conservation of Energy*)

Not only is a body capable of performing work in consequence of its motion, but also by

means of its condition with regard to heat and light, its electrical state, and its molecular arrangement, and in the widest sense of the term all these sources of work are included under the term energy, hence there will be as many different kinds of energy as there are kinds of force, capable of performing work Forces may be divided into two classes, those capable of producing perceptible motion, and those which act only between the molecules of the body, hence there are two great divisions of energy, *Visible Energy* and *Molecular Energy* To the first class belong the kinetic energy of a body in visible motion, and the potential energy of a body suspended in a position from which it may be let fall There is visible potential energy in a watch newly wound up, in a bent cross bow, and in a head of water To the second division belong the forms of energy arising from electricity, light, heat, and chemical action Each of these kinds resolves itself into two divisions, one analogous to the kinetic energy of a moving body, and the other to its energy of position For instance, when a current of electricity is passing along a wire it will deflect a magnetic needle, so that the needle will no longer point N and S, but will set itself across the current, and by passing round a bar of soft iron, it will cause the bar to become a magnet, and powerfully to attract pieces of steel or iron near it The energy of electricity in motion may be termed actual or kinetic When two electrified bodies are suspended near one another they will repel or attract one another according as they are charged with like or unlike electricities, hence two such bodies possess an advantage with regard to electrical separation which may be termed potential energy Again, radiant heat and light is a species of actual energy which passes through space with an enormous velocity, and produces motion in the molecules of the bodies which intercept it The energy resulting from the expansion of a body in consequence of heat is potential The energy stored up in the sulphur, saltpetre, and charcoal which form gunpowder is an example of the potential energy due to chemical separation The following is therefore a table of the kinds of energy —

		Kinetic	Potential
sible Energy		Due to visible motion	Due to a position of advantage
Molecular Energy,	Electricity	Due to electricity in motion	Due to electrical separation or opposite electrical states
	Heat	Radiant heat and light, absorbed heat	Potential energy of absorbed heat
	Chemical Action	Due to actual chemical action	Due to chemical arrangement

(See *Transmutation of Energy*)

ENGINE (Fr *engin*, from L *ingenium*) Any compound machine composed of different parts intended to apply the principles of the mechanical powers (See *Steam Engine, Heat-Engine, Gas Engine*)

ENIF (Arabic) The star ε of the constellation Pegasus

ENDOSMOSE (ενδον, within, and ωσμος, impulsion) The passage of a liquid or gas through a porous diaphragm inwards (See *Osmose*)

EPACT (επακτος, added) In chronology this term indicates the date of the first new moon of the year Thus if the first new moon occur on January 10, the epact for the year is 10 As 12 lunar months contain 354 days, or 11 short of 365, the epact for the following year will be 10 + 11 or 21, unless the year be bissextile, in which case the epact will be 22 The epact is now chiefly used for ecclesiastical purposes

EPHEMERIS (ἐφημερίς, a diary) An astronomical table predicting the place of a celestial object day after day In the Nautical Almanac, the French Connoissance des Temps, the Berlin Jahrbuch, and the American Nautical Almanac, carefully computed ephemerides of the sun moon and planets are published three or four years in advance

EPIPOLIC DISPERSION See *Fluorescence*

EPSOMITE See *Sulphates, Magnesium*

EPSOM SALTS See *Sulphates, Magnesium*

EPOCH (Ἐπέχω, to stop) In astronomy, the moment of time to which the elements of a planet's orbit are referred

EQUATION In astronomy, any number or quantity that has to be applied to the mean value of another number or quantity to obtain the true value (See *Equation, Personal, Equation of the Centre, Equation of Time*)

EQUATION OF CENTRE The apparent motion of the sun along the ecliptic is not uniform, because the earth moves with variable angular velocity round him When the earth

is in aphelion, the sun seems to move most slowly because the earth is really moving with her least angular velocity, and on the contrary, when the earth is in perihelion, the sun appears to move most swiftly The actual daily motion of the sun in the ecliptic varies thus between the values 0° 57′ 11 50″, and 1° 1′ 9 90″, his mean motion being 0° 59′ 58 64″ Now supposing that an imaginary sun were to travel uniformly round the ecliptic in the same time as the real sun, both starting together from the point where the sun is in perihelion, it is obvious that the real sun would at first pass in advance of the imaginary one, but that as they approached the point where the sun is in aphelion, the imaginary sun would gain on the real one, and they would reach that point together, after passing that point the imaginary sun would be in advance, but as they approached their starting point, the real sun would gain on the imaginary one and they would reach that point together The apparent distance separating the centres of the two suns is called the *Equation of the Centre*, and has to be considered in comparing real and mean solar time (See *Equation of Time*) The equation of the centre never exceeds 1° 55′ 33 3

EQUATION OF EQUINOXES The position of the equator on the ecliptic is continually shifting backwards (see *Precession*), but not at a uniform rate A mean rate of motion is therefore assumed, and the correction due for the variation from uniformity is given in the Nautical Almanac, and other such works, for every ten days This correction is called *the Equation of the Equinoxes*

EQUATION OF TIME A correction which has to be applied to apparent solar time, to determine mean solar or civil time, and to mean time to determine apparent time If the sun travelled uniformly along the equator, mean and apparent time would coincide, as he travels with variable velocity on the ecliptic, they differ Now as respects his variable velocity, the reader will see by a reference to *Equation of Centre* what its effects are, but so far as they influence the correction for time, a few words must be added Supposing there were no other correction than this, and we selected the epoch of the earth's perihelion passage as that on which true and mean time coincided Then we have seen that the sun passes in advance of the place due to his mean motion, and since it is the sun's motion in the ecliptic which causes the solar day to exceed the sidereal day (for this motion takes place in a direction contrary to that of the diurnal rotation), we see that the faster the sun moves, the longer the true solar day becomes, and that so long as the sun is in advance of his mean place he comes later to the meridian, so that when the true sun shows noon it is really past noon Hence until the earth is in aphelion the correction on apparent time is *additive* It is equally clear that while the earth is moving from aphelion to perihelion, the correction on apparent time is *subtractive* Thus so far as the sun's variable motion in the ecliptic is concerned, we have, from the beginning of January to the beginning of July, an additive correction, and through the rest of the year a subtractive correction Next, as to the sun's oblique motion Supposing that in this case, for convenience, we regard the apparent and mean time as coincident when the sun is at the solstices and equinoxes Then starting from the winter solstice, we see that the true sun passes in advance of the mean sun in right ascension, because he is travelling athwart the circles of declination where they are nearer together than on the equator, but as he nears the equator he travels more slowly than the mean sun in right ascension, because he travels athwart the circles of declination obliquely and where they are nearly as far apart as on the equator On the equator the true and mean sun come together Thence to the summer solstice the true sun is behind the mean sun, thence to the autumnal equinox in advance, and thence to his starting place, at the winter solstice, behind Thus we get —From the winter solstice to the vernal equinox, an additive equation, thence to the summer solstice a subtractive one, thence to the autumnal equinox an additive one, and finally, thence to the winter solstice, a subtractive one

Combining this result with the former, calling the correction due to the sun's variable velocity A, and that due to his oblique course B, and supposing for the moment that the earth is in perihelion at the winter solstice (which is not far from the truth), we get from the winter solstice to the vernal equinox A and B, both additive, A passing from 0 to its maximum, B from 0 through its maximum to 0 again, thence to the summer solstice A is additive, B subtractive, A passing from its maximum to 0, B from 0 through its maximum subtractive value to 0 again, thence to the autumnal equinox A is subtractive and B additive, A passing from 0 to its maximum, B from 0 through its maximum additive value to 0 again, and lastly, thence to the vernal equinox, A and B are both subtractive, A passing from its maximum to 0, and B from 0 through its maximum to 0 again According to this arrangement, we should have the winter solstice and the summer solstice at two epochs when the equation of time was *nil*, and the equation would also vanish in the course of spring and summer, through the equality and contrary character of A and B As a matter of fact, owing to the non-coincidence of the earth's perihelion with the winter solstice, there is not this simple relation Somewhere between the winter solstice and the date of the earth's perihelion passage, the equation of time

is *nil*, this happens on or about Christmas-day, and the equation again vanishes on or about June 16th, the equation vanishes also on or about April 16 and September 1st The four maxima are unequal, their character and amount are as follows —On February 11th an additive maximum equation of $14^m\ 31^s$, on May 14, a subtractive maximum equation of $3^m\ 53^s$, on July 16 an additive maximum equation of $6^m\ 13^s$, and lastly, on November 3, a subtractive maximum equation of about $16^m\ 19^s$, the absolute maximum for the year

EQUATION, PERSONAL In astronomy, a correction applied to time intervals depending on observations made by different persons In noting the occurrence of a given astronomical event, different observers will make errors which differ in character or extent One observer will record the event too soon, another too late, or the average error made by two observers, both of whom anticipate the event, or fail to record it in time, will be found to be different Now when it is possible, by comparing a long series of observations made by two astronomers, to determine the average difference between the errors likely to be made by each, it becomes possible to make an important correction of time intervals depending on their combined observations Thus suppose A records an event as having happened at a certain time, while B records another event as having happened 10 minutes later Now if we know that in recording the same event, A would anticipate B by 1 second, we conclude that if either A or B had observed both events, the time interval would have been $9^m\ 59^s$, instead of 10^m, whether A or B be the more exact observer This then is the estimated interval between the occurrence of the two events, and 1″ is the *relative personal equation* between the two observers When we have the means of learning what actual error an observer is likely to make, we can also apply to his observations a correction equivalent to this error This correction would be his *absolute personal equation*

EQUATOR, CELESTIAL (*Æquus*, equal) In astronomy the great circle on the heavens which has for poles the intersection of the earth's axis of rotation with the celestial sphere When the sun is on the equator the day is equal to the night for all places on the earth's surface Hence the name of this great circle Right ascension is measured along the equator from the first point of Aries Declination is measured from the equator along declination circles, either towards the north or south pole The equator is sometimes called the *equinoctial*

EQUATORIAL In astronomy, a term applied to a telescope which has its fixed axis directed to the pole of the heavens, so that the telescope may be made to follow a star by a single motion

EQUATORIAL HORIZONTAL SOLAR PARALLAX See *Parallax*

EQUATOR, MAGNETIC A line which pretty nearly coincides with the geographical equator, and at every point of which the vertical component of the earth's magnetic attraction is zero —that is to say, a dipping needle carried along it remains horizontal It is hence called the *Aclinic Line* (See *Aclinic*)

EQUATOR, TERRESTRIAL The great circle on the earth which is at right angles to the polar axis, and so divides the earth into two hemispheres—the northern and the southern

EQUILATERAL PRISM (*Æquus*, equal, and *latus*, a side) A prism, the section of which, perpendicularly to its axis, is an equilateral triangle This form and the isosceles prism are those usually employed to effect the prismatic decomposition of light

EQUILIBRIUM (From *æquus*, equal, and *libra*, a balance) The state of rest of a point or body acted on by a system of mutually counteracting forces Any relation between the forces which can only exist when there is equilibrium, and which must exist in order that there may be equilibrium, is termed the condition of equilibrium The condition that two forces acting on a particle shall keep it at rest, is that the forces be equal and opposite The condition of equilibrium for three forces may be expressed in various ways — The resultant of any two of the forces must be equal and opposite to the third, if a triangle be formed by lines parallel to the directions of the forces, the sides will be proportional to the forces When any system of forces in one plane acts on a point at rest, if the forces be resolved into two sets in directions at right angles to one another, the forces acting in either direction must be an equilibrium amongst themselves When the forces are not in the same plane, the same condition holds, with regard to three directions, at right angles to one another When the forces are parallel, and in one plane, in order that there may be equilibrium, the sum of the moments of the forces about any point in their plane must be zero When the forces act on a rigid body, there are usually two conditions of equilibrium, the one being the condition that the body shall not have a motion of translation, and the other that it shall not have a motion of rotation. For example, the conditions of equilibrium of a lever are—first, that the fulcrum shall be strong enough to bear the pressure upon it, and, secondly, that there shall be no tendency in the lever to turn about the fulcrum, hence the resistance of the fulcrum must be equal to the sum of the

power and weight, and the moment of the power about the fulcrum must be equal to the moment of the weight. When a body is suspended from a point, the resistance of the point must be equal to the weight of the body, and the vertical through the point must contain the centre of gravity of the body. The same two conditions hold when a body rests on a point. If a body rest on more than one point in the same plane, the resistances at these points will be parallel forces, and will therefore have a single resultant parallel to them. The direction of this resultant will lie within the base formed by the points, hence a condition of equilibrium is that the vertical through the centre of gravity of the body must fall within the base.

The force required to move a body may vary with the position of the body. Let a prism rest on a horizontal plane, and let it be turned about one edge. The centre of gravity will describe a circle, and the force required to move the prism will decrease as the centre of gravity ascends; in other words, the stability of the body decreases as the centre of gravity rises. When the centre of gravity arrives at a position vertically over the edge, the body reaches the limit of stability. The equilibrium is mathematically possible in this position, but the slightest force would destroy it, and when slightly disturbed the body would fall away from the position.

When a body in equilibrium would return to its original position, if slightly displaced, the equilibrium is said to be *stable*; when the body would fall away from its first position if slightly displaced the equilibrium is said to be *unstable*; when there is neither a tendency to return to, nor to fall away from the first position, the equilibrium is *neutral*. There is equilibrium only when the centre of gravity occupies the highest or lowest possible position, and the equilibrium is stable in the first, and unstable in the second. In the case of neutral equilibrium, as, for instance, when a sphere rests on a horizontal plane, the centre of gravity is neither raised nor lowered by moving the body.

EQUINOCTIAL. See *Equator, Celestial*, and *Equinox*.

EQUINOCTIAL POINTS. The points in which the ecliptic intersects the celestial equator. The point in which the ecliptic passes to the north of the equator corresponds to the vernal equinox (see *Equinox*), and is called the *first point of Aries*. The point in which the ecliptic passes to the south of the equator corresponds to the autumnal equinox, and is called the *first point of Libra*. Owing to precession, the equinoctial points shift retrogressively along the ecliptic; so that, for example, the first point of Aries now falls within the constellation Pisces, the first point of Libra within the constellation Virgo. A complete revolution is effected in 25,868 years.

EQUINOCTIAL TIME. Time may sometimes be conveniently referred to the passage of the first point of Aries across the equinox. This is called *equinoctial* time, to distinguish it from *local time*.

EQUINOX. (*Æquus*, equal; and *nox*, night.) The period when the sun crosses the celestial equator. His passage from south to north of the equator which occurs on about the 21st of March, marks the period of the *vernal equinox*; his passage from north to south of the equator, which occurs on about the 23rd of September, marks the period of the *autumnal equinox*. Owing to the ellipticity of the earth's orbit, the interval between the vernal and the next autumnal equinox is nearly eight days greater than the interval between the autumnal and the next vernal equinox; for the earth passes her perihelion in mid-winter, and then moves most swiftly in her orbit, whereas in mid-summer she passes her aphelion, and moves most slowly. It is necessary to remark that for the southern hemisphere the vernal and autumnal equinoxes are interchanged; and the southern summer is, of course, shorter than the southern winter.

EQUULEUS. (The *Little Horse*.) One of Ptolemy's northern constellations. It lies close by Delphinus, and is equally insignificant.

ERBIUM. A very rare metallic element accompanying Yttrium and Terbium; no method of separating them accurately is known. Its salts appear to be colourless, and to crystallise well, but their properties are almost unknown. Symbol Er. The atomic weight has not been determined. According to Bunsen, the oxide *Erbia* when ignited in a spirit lamp gives a spectrum consisting of luminous bands. Mr Huggins has recently shown that some other earths possess this property. *Chem. News*, Oct. 7th, 1870.

ERECTING EYEPIECE. This form of eyepiece is generally used for terrestrial telescopes, and is seldom employed for microscopes or astronomical telescopes. It consists of an ordinary negative eyepiece in front of which two lenses are placed which erect the inverted image formed by the object glass, the negative eye-piece then enables the observer to view this erect image. (See *Eye-piece*, and *Telescope*.)

ERIOMETER. (*εριον*, fibre; *μετρον*, a measure.) An instrument proposed by Dr Young for measuring the diameters of minute particles and fibres; it depends upon the diffraction fringes formed by the object to be measured. As these fringes increase with the size of the object it is not difficult to form a scale of measurement based on this principle. (See *Fringes*.)

ERIDANUS One of Ptolemy's southern constellations It ranges over a great extent of sky, following a winding course from the preceding foot of Orion, past the paw of Cetus, towards the keel of Argo The principal star of this constellation, the brilliant Achernar, is not visible in our latitudes

ERRAI (Arabic) The star γ of the constellation Cepheus

ESCAPEMENT In horology, the name given to that part of the mechanism by which the circular motion of the wheels is converted into a vibratory motion (See *Horology*) There are several common forms of escapement

The *clutch* or *anchor* escapement was invented in 1680 by Clement, a London watchmaker, and was greatly improved by Graham about the year 1700 The pendulum is attached to a double hook termed a clutch or anchor, which falls between the teeth of the escapement wheel, and then *escapes* from it once in each oscillation The escapement wheel has teeth bent in the direction opposite to that in which it is to move, forms part of the clock work, and is moved by the weight or spring It revolves, however, with a motion which is not continuous, as would be the case if the anchor did not intervene, but is stopped alternately by one spur or *pallet* of the anchor, and then by the other As the time of oscillation of the anchor depends on the length of the pendulum, the latter regulates the motion of the escapement wheel, and by its means the motion of the other parts The motion of the escapement wheel continues only for the short interval during which the tooth of the wheel slides over the pallet of the anchor, and the wheel is still or dead during the remainder of the oscillation On this account the anchor escapement is sometimes termed the *dead beat* escapement The *recoil* escapement consists of two spurs or pallets, which project from the balance wheel of a watch, at right angles to each other, one acting at the top and the other at the bottom of the escapement wheel These pallets engage alternately in the teeth of the escapement wheel exactly in the same manner as the pallets of the anchor

The *cylindrical* escapement is used in very flat watches The pallets are replaced by notches in the axes of the balance-wheel, which is formed into a semi cylinder As the balance wheel oscillates the semi cylinder turns upon its axis and interposes itself alternately on the right and on the left between the teeth of the escapement wheel, letting them escape in a manner exactly similar to that of the anchor

The *duplex* escapement consists of an escapement wheel with two sets of teeth partaking of the characters of a spur and a crown wheel and an impulse claw or pallet The spur teeth are like those of the ordinary escapement wheel, and the crown teeth project from the face The pallet falls successively between the crown teeth, and receives from them as they escape an impulse which keeps up the motion of the balance wheel

The *detached* or *lever* escapement is now much used in English pocket watches It consists of an anchor attached to a lever forked or notched at one end A pin attached to the *verge* or axle of the balance enters the notch at each vibration, first moving off the anchor and then receiving an impulse which restores the force lost The lever is detached from the balance except for an instant at the middle of each oscillation (See *Horology*)

ESSENTIAL OILS See *Oil*

ETANIN (Arabic) The star γ of the constellation Draco It is interesting as being the star by the observation of which Bradley was led to the discovery of the aberration of the fixed stars

ETESIAN WINDS The heat of Sahara in summer causes cool air from the Mediterranean to flow southwards The winds thus arising are called Etesian winds

ETHER A very mobile colourless liquid, having a peculiar fresh odour and burning taste. Specific gravity, 0 723 Boiling point, 35 5° C (96° F) Formula, $C_4H_{10}O$ It is very inflammable, and the vapour forms an explosive mixture with air It dissolves slightly in water In its chemical relations ether is considered to be the oxide of the radical *ethyl* (C_2H_5), common alcohol being the *hydrated oxide of ethyl* Ether is the second term of a series of homologous bodies of which methylic ether (C_2H_6O), is the first (See *Alcohols, Homologous Substances*)

ETHER, LUMINIFEROUS (Αἴθω, to light up , αἰθήρ, ether) The medium whose vibrations are supposed to cause light. It is believed to pervade all space, and to be imponderable and infinitely elastic (See *Undulatory Theory of Light*)

ETHYL A colourless gas Specific gravity, 2 046 At 38° F (3 3° C), it assumes the liquid form, under a pressure of 2½ atmospheres Boiling point about − 9 4° F (− 23° C) The gas burns with a highly luminous flame

EUCHLORINE See *Chlorine*

EUDIOMETER (εὔδιος, fine, clear, of air, and μέτρον, a measure), is an instrument for examining the composition of gases, originally for testing the purity of air by ascertaining the quantity of oxygen it contains. There are several forms of eudiometer, the most convenient is

perhaps a straight graduated glass tube closed at the top, and having two platinum wires hermetically sealed into its sides, and projecting into the interior, so as *nearly* to touch each other, or a U tube, one of whose legs is closed, graduated and furnished with platinum wires in the way we have just described

The method of examining a mixture of gases with this instrument will readily be understood from the following description —Suppose a specimen of common air is to be analysed, a certain volume is introduced into the eudiometer, standing over mercury in the usual way, for collecting gases, and the amount carefully noted by means of the graduations of the tube To determine the carbonic acid gas present a small quantity of very strong solution of caustic potash is then thrown up into the tube, and by moving it up and down, while the mouth of it is always carefully kept beneath the surface of the mercury, the carbonic acid gas is caused to combine with the caustic potash, and to be absorbed into the liquid, thus giving rise to a diminution of the volume of the gas, which is noted If there be other impurities they are determined by means of suitable absorbents The oxygen may then be absorbed by means of alkaline solution of pyrogallic acid (*q v*), and the nitrogen found by difference, but we prefer to describe the following method of ascertaining its quantity in order to illustrate one of the uses of the eudiometer Supposing that there is nothing left but a volume of oxygen and nitrogen, and that it is required to find the amount of oxygen in the mixture, a quantity of pure hydrogen is added, whose volume is at least twice that of the oxygen contained in the mixture, and the amount is carefully noted An electric spark is then caused to pass between the platinum wires, which we have described as sealed into the tube, and on its passage the oxygen and hydrogen combine (see *Electro-Chemistry*) to form water In order to prevent a loss of gas when the explosion takes place, the lower end of the eudiometer is depressed while the spark passes a few inches below the level of the mercury if the straight tube be used, and care is always taken in filling the tube to leave a space of at least an inch at the bottom occupied by a column of mercury If the bent eudiometer is employed, the open end is closed with the thumb, the bend of the tube being filled with mercury As soon as the tube is cool, the water, which is formed as steam, condenses, and the volume of the gas that has disappeared in the form of water is carefully noted, the proper corrections for temperature and pressure being made But we know that oxygen and hydrogen combine together to form water in the proportions of two volumes of hydrogen to one of oxygen, and hence one-third of the gas that has disappeared is oxygen Subtracting this volume from the volume of the mixture of oxygen and nitrogen determined before the addition of the hydrogen, the original volume of nitrogen is known In an analysis the results obtained are then reduced to per centage volumes

EVAPORATION (*Evaporo*, to disperse in vapour) Evaporation signifies the formation of vapour at the surface of a liquid, in contradistinction to ebullition, which signifies the formation of vapour within the mass of a liquid Evaporation takes place from every exposed liquid surface and at all temperatures, it varies with the area of the surface exposed and with the temperature of the surrounding space It was once imagined that the air itself induced evaporation in virtue of its attraction for the vapour, but this is well known to be false, because evaporation takes place in a vacuum far more freely than in air It also takes place more readily in the presence of dry air, and of air in motion, than in that of moist air and of air at rest Moist air is already more or less saturated with vapour, and, when quite saturated, evaporation ceases, now the air immediately above a liquid, so long as it is at rest, is saturated with vapour, but if the air be in motion, unsaturated portions are constantly brought in contact with the surface, and the evaporation is thus promoted The influence of temperature on evaporation scarcely needs any illustration As heat is the cause of evaporation, it is obvious that the higher the temperature, other things being equal, the greater will be the evaporation, and we have numberless examples of this around us We know how soon the earth becomes parched in summer, and how rapidly streamlets and small lakes dry up in warm weather The influence of extent of surface is also obvious, for, since evaporation takes place only from the surface of a liquid, the greater the surface the greater must be the evaporation If we take a tumbler of water and place it in the sun, side by side with the same amount of water in a flat dish, the difference in the evaporation will soon be apparent Salt was formerly procured by the evaporation of sea water in shallow "salt pans" of very large area Evaporation takes place more readily in a vacuum than in air on account of the reduced pressure, because pressure of necessity tends to keep the molecules of the liquid together, and when that pressure is removed, the molecules can more readily assume the gaseous condition If a drop of a volatile liquid be passed up into the Torricellian vacuum, it instantly assumes the vaporous condition The influence of pressure on the boiling point is discussed in detail in the article *Ebullition* When a liquid is evaporated simultaneously in a vacuum, and in the presence of a substance like sulphuric acid or chloride of calcium, which has a great attraction for moisture, the evaporation is

very rapid The influence of air in motion as a promoter of evaporation can be shown by many means Thus, the action of a fan is to increase the evaporation from the skin and so to produce cold, so, also, if we moisten the face and then fan ourselves, we perceive a considerable chilling, and if ether is poured upon the hand and air blown upon it the cold is intense

The production of gas or vapour (and we may here remark that the term *gas* is usually applied to substances in the gaseous condition which are far removed from their points of condensation, while the term *vapour* is applied to gases which normally exist in the liquid condition), is always and of necessity accompanied by the production of cold—that is, by the withdrawal of heat, for cold is not an entity A gas or vapour is a liquid *plus* heat, and in the passage from the liquid to the gaseous condition a quantity of heat is rendered latent (see *Latent Heat*), which reappears on the liquefaction of the gas or vapour Water and other liquids may be frozen by their own evaporation, as was first shown by Leslie In order to effect this, he placed a small vessel containing water immediately over a dish full of concentrated sulphuric acid, this was put under the receiver of an air pump, which was exhausted, the consequence was that the water evaporated rapidly, and the vapour was absorbed by the sulphuric acid until the water had been so cooled by the withdrawal of the heat necessary for its vapour that it froze We have another example of the freezing of water by its own evaporation in Dr Wollaston's *Cryophorus* (which see) Extreme degrees of cold may be produced by the evaporation of very volatile liquids, such as we have in the liquefied gases Thus mercury may be frozen by the evaporation of liquid sulphurous acid, and the most intense degree of cold with which we are acquainted is produced by the evaporation of a mixture of liquid nitrous oxide with bisulphide of carbon in a vacuum

The elastic force of a vapour depends on the temperature, and is greater as the temperature is higher The following law relating to this result was discovered by Dalton —In a vacuum the evaporation of a liquid continues until the vapour has attained a definite elastic force, which is dependent on the temperature, hence, in a space devoid of air and saturated with vapour, a definite pressure corresponds to a definite temperature In the following tables, somewhat condensed from Lardner's "Natural Philosophy," the relation between the temperature, pressure, volume, and mechanical effect of aqueous vapour are shown at various temperatures —

TABLE SHOWING THE PRESSURE, VOLUME, AND DENSITY OF AQUEOUS VAPOUR AT VARIOUS TEMPERATURES

Temperature Fahrenheit	Pressure		Volume of vapour containing unit of volume of water	Density of vapour (Density of water = 1)	Mechanical effect in lbs raised 1 foot
	Inches of Mercury	Pounds per square inch			
− 4°	0.052	0.03	650583	0.00000154	1395
+ 14	0.104	0.05	342984	0.00000292	1451
23	0.144	0.07	251358	0.00000398	1480
32	0.199	0.10	182323	0.00000540	1483
41	0.274	0.13	137488	0.00000727	1536
50	0.373	0.18	102670	0.00000974	1565
60.8	0.537	0.26	72913	0.00001372	1598
71.6	0.764	0.37	52260	0.00001914	1632
80.6	1.019	0.50	39895	0.00002507	1661
91.4	1.425	0.70	29112	0.00003435	1694
100.4	1.873	0.92	22513	0.00004442	1722
111.2	2.584	1.27	16805	0.00006023	1774
120.2	3.322	1.63	13151	0.00007602	1785
131	4.477	2.19	9946	0.00010054	1819
140	5.695	2.79	7937	0.00012599	1847
150.8	7.530	3.69	6114	0.00016356	1881
161.6	9.852	4.83	4759	0.00021013	1915
170.6	12.224	5.99	3891	0.00025699	1943
181.4	15.680	7.69	3087	0.00032399	1977
190.4	19.138	9.38	2565	0.00038984	2005
201.2	24.062	11.80	2075	0.00048201	2040
204.8	25.908	12.70	1938	0.00051613	2051
206.6	26.874	13.17	1873	0.00053388	2056
208.4	27.860	13.66	1812	0.00055191	2062
210.2	28.877	14.16	1751	0.00057055	2066
212	29.921	14.67	1696	0.00058955	2073

When the pressures are considerable they are given in atmospheres, the pressure of one atmosphere being equal to that of thirty inches of mercury

TABLE SHOWING THE TEMPERATURE, VOLUME, AND DENSITY OF AQUEOUS VAPOUR, AT PRESSURES VARYING FROM ONE TO FIFTY ATMOSPHERES

Pressure in Atmospheres	Temperature Fahrenheit	Volume of vapour produced by unit of volume of water	Density of vapour (Density of water = 1)
1	212 00	1696 00	0 0005895
2	250 52	897 09	0 0011147
3	275 18	619 19	0 0016151
4	293 72	476 26	0 0020997
5	307 58	388 16	0 0025763
6	320 36	328 93	0 0030402
7	331 70	286 12	0 0034911
8	341 78	253 59	0 0039434
9	350 78	227 98	0 0043865
10	358 [illegible]	207 36	0 0048226
11	366 80	190 27	0 0052557
12	374 00	175 06	0 0056834
13	380 66	163 74	0 006107
14	386 90	153 10	0 006527
15	392 90	144 00	0 006944
16	398 48	135 90	0 007359
17	404 88	128 71	0 007769
18	408 92	122 28	0 008178
19	413 78	116 51	0 008583
20	418 46	111 28	0 008986
21	422 96	106 53	0 009387
22	427 28	102 19	0 009785
23	431 42	98 21	0 010182
24	435 56	94 56	0 010575
25	439 34	91 17	0 010968
30	457 16	77 50	0 012903
35	472 64	68 20	0 014663
40	486 50	60 08	0 016644
45	499 10	54 06	0 018497
50	510 62	49 31	0 020306

A certain amount of vapour is produced from water at very low temperatures, thus, at the freezing point, the tension of aqueous vapour is sufficient to depress the barometric column one fifth of an inch, and ice at a temperature of —4° F (—20° C) emits aqueous vapour of sufficient tension to depress the column of mercury one twentieth of an inch

A vapour, if it be produced from colourless liquid, is colourless and transparent, like air, if, on the other hand, it is produced from a coloured liquid, such as bromine, it possesses the same colour, but is perfectly transparent Vapours are elastic, and various means have been devised for showing their elasticity When a volatile liquid is passed up into the Torricellian vacuum, it immediately becomes vapour, and the column of mercury is depressed The extent of the depression measures the volatility of the liquid When a certain amount of liquid has been introduced, we notice that it is no longer converted into vapour, but it floats on the surface of the mercury Evaporation has now ceased, because the vacuous space is *saturated* with vapour, and the elastic force of the vapour is at a maximum

A second law of considerable importance as regards evaporation was discovered by Dalton He found that a liquid evaporates to the same extent in a space filled with air as in a vacuum, and that the same relationship exists between the temperature and the elastic force of the vapour, whether the space contains air or not A liquid evaporates far more slowly in a space containing air (or gas of any kind which does not act upon it) than in a vacuum, but the ultimate result is the same

See also *Leidenfrost's Experiment*

EVECTION A lunar inequality (See *Lunar Theory*)

EVENING STAR The name given to the planet Venus when she sets after the sun She is then approaching inferior conjunction and increasing in apparent diameter

EXCHANGES, LAW OF The law that the relation between the amount of heat emitted

and that which is absorbed at any *given temperature* remains *constant for all bodies*, and that the greater the amount of heat emitted the greater must be the amount of heat absorbed. This was partially enunciated by Prevost and by Prevostaye and Dessains, and extended by Dr Balfour Stewart ("Report on the Theory of Exchanges," by B. Stewart, Brit. Assoc., 1861). Kirchhoff has proved that the same law holds good for light as well as for heat (Roscoe). (See also *Spectrum Analysis*, *Theory of Exchanges*.)

EXOSMOSE (ἐξ, out of; ὠσμος, impulsion). The passage of a liquid or gas through a porous diaphragm outwards. (See also *Osmose*.)

EXPANSION (*ex*, out; *pando*, to spread or open). Heat has been elsewhere defined as a very rapid reciprocal motion of the small particles or molecules of matter. (See *Heat*.) Now it is reasonable to infer that the addition to a number of molecules possessing a certain amount of this motion, of more of the motion, would, by producing a greater commotion, cause the molecules to occupy a larger space; and this we find to be the case. Heat expands all bodies, and moreover the amount of heat associated with a body determines its form; that is, whether it be existing as a solid, a liquid, or a gas. The molecules of matter possess an attraction for each other, called *cohesion*, and in antagonism to this there is the force of heat which may be regarded as repulsive, because an addition of motion to a congeries of particles must tend to separate them, that is, to act against cohesion. In a solid, say ice for example, the cohesion of the particles is sufficient to keep them comparatively close together, for although they are by no means in contact, and are endued with the vibratory motion called heat, the cohesive force is the stronger of the two, and keeps the particles within the range of its attractive influence. If now we add heat to the ice, it assumes the liquid form, and we must imagine that the force of cohesion tending to keep the particles together, is now equal to the force of heat tending to separate them; the actions are in fact balanced, and we have a freeness and mobility in the particles which in the solid form they did not possess. If the water is again heated it assumes the gaseous form, it becomes steam or water-gas. The cohesion of its particles is now entirely overcome, they have received so much motion that they have been carried beyond the [illegible] of cohesion, and are now alone actuated by the motion of heat. Thus, in a solid the molecules are nearest to each other, in a liquid they are less near, and in a gas they are least near, and are unrestrained in their motion. In the passage from solidity to gaseity, there is a progressive decrease of cohesive force arising from a progressive augmentation of the space between the attracting molecules, and a progressive increase of molecular motion arising from the direct addition of heat; while in the passage from gaseity to solidity there is a progressive increase of cohesive force, arising from the diminution of the space between the attracting molecules, and a progressive decrease of molecular motion arising from the direct transference of heat. Solids continue to expand until they pass into the liquid form, and liquids continue to expand until they pass into the gaseous form.

1. *Expansion of Solids*. The expansion of solids may be shown by various means; if we take a bar of metal which when cold will just pass between two rigid metal surfaces by which its length can be gauged, it is found after heating to no longer pass; or, if a metallic ball is passed when cold through a ring of metal of very slightly greater circumference than its own, it is found after heating that the ball now rests on the ring without passing through it. This apparatus which is known as *S'Gravesande's Ball*, was devised about 250 years ago, and is figured in S'Gravesande's *Physices Elementa Mathematica*. This illustrates cubical expansion.

Linear expansion may be shown by fixing a bar of metal at one end and causing the other end to press against a lever or system of levers by means of which any lengthening of the bar may be multiplied, and at the same time indicated by a pointer; on heating the bar the movement of the index at once shows that it has lengthened. Uncrystallised solids, when heated uniformly, expand uniformly in length, breadth, and thickness, and we can speak either of the *linear* expansion, the *superficial* or surface expansion, or the *cubical* expansion of a substance. The *coefficient of linear expansion* is the increase in length of a substance, for one degree of temperature, whose length at some given temperature, generally 0° C. (or 32° F.), is taken as unity. Thus, if the length of a brass rod at the freezing point (32° F.) be taken as 1.000000, its length at the temperature of boiling water (212° F.) is found to be 1.001867, and the linear coefficient of expansion of brass for 180° F. (212° − 32°) is hence 0.001867, and for 1° F. = 0.001867 ÷ 180 = 0.00001038. The *coefficient of superficial expansion* is in like manner the increase of surface for one degree of temperature of a surface taken as unity at 32° F.; and the *coefficient of cubical expansion* is the increase of volume of a volume taken as unity. It can well be imagined that different bodies expand to a very different extent for equal increments of heat, because the force of cohesion must necessarily vary with the nature of the substance, and the form and arrangement of its molecules. The following table shows the linear expansion of certain substances.

LINEAR EXPANSION OF SOLIDS

Name of Substance	Length of a bar at 212° F whose length at 32° F is 1·000000	Name of Observer
Antimony,	1·00108300	Smeaton
Bismuth,	1·00139167	"
Brass,	1·00185540	Roy and Ramsden
" plate, in rod, . .	1·00189780	" "
"	1·00186671	Lavoisier and Laplace
Copper, .	1·00172244	" "
"	1·00171821	Dulong and Petit
Glass,	1·00086130	" "
" white, (barometer tube),	1·00083333	Smeaton
" English flint,	1·00081166	Lavoisier and Laplace
" French containing lead,	1·00087199	" "
" tube, without lead,	1·00067572	" "
" from St Gobain,	1·00089089	" "
Gold, (Paris standard, annealed),	1·00151361	" "
" " " unannealed,	1·00155155	" "
Iron,	1·00125833	Smeaton
"	1·00115600	Borda
" soft, forged, .	1·00122045	Lavoisier and Laplace
" round, wire-drawn,	1·00123504	" "
"	1·00118203	Dulong and Petit
" cast, .	1·00110940	Roy and Ramsden
Lead, . .	1·00284836	Lavoisier and Laplace
"	1·00286700	Smeaton
Platinum,	1·00085655	Borda
"	1·00088420	Dulong and Petit
Silver, (Paris standard),	1·00190868	Lavoisier and Laplace
Speculum metal,	1·00193333	Smeaton
Steel untempered,	1·00107875	Lavoisier and Laplace
" tempered yellow,	1·00123956	" "
Tin, from Malacca,	1·00193765	" "
" " Falmouth,	1·00217298	" "
Zinc,	1·00294200	Smeaton

Although these expansions appear excessively small, the influence of heat is more considerable than we are apt to imagine when a great length of substance is considered. For example, the railroad between London and Edinburgh is 400 miles long; let us inquire the difference in length of the rails in summer and winter. Now, iron expands 0·001235 of its length for 180° F., hence the expansion for 1° F. is equal to 0·001235 ÷ 180, that is to 0·00000686. The extremes of summer and winter temperatures may fairly be taken as 70° F. Hence the 400 miles of iron rails will expand 0·00000686 × 70 = 0·00048020 of its length for the total variation of temperature; and as there are 704000 yards in 400 miles, we find at once, by multiplying this number by 0·0004802, that in summer the rails are 338 *yards* longer than in winter. It at once becomes obvious that if the rails were placed in contact considerable displacement and distortion would arise.

It is necessary to make allowance for expansion and contraction in all instances in which great lengths of metal are employed, as in buildings, iron bridges, iron rails, gas and water pipes, and so forth; if space is not allowed for the expansion produced by the warm temperature of summer, the metals either become distorted, or loosen the masonry with which they are in contact. A space is always left between each rail of a line of railway, otherwise the metal being restrained at both ends, bends when expanding, either laterally or upwards. The laws which regulate the expansion of bodies have been applied to various purposes, notably to compensating pendulums (which see). For an account of the force exercised by substances during expansion, and the subsequent contractile force see *Interior Work*, *Molecular Potential Energy*.

The superficial expansion of a substance is equal to twice its linear expansion, and the cubical expansion to three times the linear. Thus the cubical expansion of glass between 32° F. and 212° F. is about ·00254, of tin, ·0069, and of iron, ·00354. Professor Matthiessen has found that the coefficient of expansion of an alloy is the mean of the coefficients of expansion of the volumes of the metals composing it. The coefficient of expansion increases with the temperature; thus, while the mean coefficient of expansion of glass for 1° C., between 0° C. and 100° C. is ·00002584, between 0° C. and 300° C. it is ·00003039; and in the case of iron, it is ·00003546, in the first instance, and ·00004405 in the second.

Certain crystals, unlike other solids, do not expand equally in all directions. Some contract in one direction while they expand in another, but the total expansion is greater than the total contraction; others expand unequally in all directions. Garnets have their density diminished by heating and recover it slowly. Iodide of silver is said to contract uniformly under the action of heat, but we have no conclusive experiments to show whether a different arrangement of its molecules is at the same time induced.

2. *Expansion of Liquids.* When an ordinary mercurial thermometer is removed from a cold to a warmer room, the mercury expands, and we have an indication of increased temperature, but the expansion observed is not the *real* but the *apparent* expansion of the mercury. The glass thermometer bulb also expands, and the expansion which we observe is therefore the expansion of the mercury *minus* the expansion of the glass envelope which contains it. If the glass expanded as much as the mercury we should observe no rise of the mercury in the tube, because one expansion would neutralise the other, and the liquid thermometers depend upon the fact that the liquid expands much more than the vessel which contains it. We must therefore very carefully distinguish between the apparent and the real expansion of a liquid under the influence of heat; the former is the apparent increase of volume undergone by a liquid contained in a vessel which expands to a less extent than the liquid for the same amount of heat; the latter is the absolute change of volume of a liquid when the expansion of the containing vessel has been subtracted or otherwise eliminated. In the case of liquids, it is obvious that *cubical expansion* can be alone considered, and we must, therefore, bear in mind the difference between the *coefficient of apparent expansion*, and *the coefficient of absolute expansion* of liquids. Liquids expand more than solids for an equal increment of heat, and we should expect this from the remarks made at the commencement of this article, as to the liquid condition of matter. A liquid is intermediate between a solid and a gas; it is a solid *plus* heat; a solid in which nearly the whole of the cohesive force is overcome; the molecules are vibrating under the influence of the motion of heat in such a manner that they approach the limit of their vibration, and the cohesion of the molecules is thus almost neutralised. Hence it is very reasonable to imagine that an addition of heat will have a greater influence upon such molecules than upon those which are more under the influence of the force of cohesion. Between the freezing and boiling points of water, that is for 180° F., or 100° C., alcohol undergoes an increase of volume of $\frac{1}{8}$th, water of $\frac{1}{23}$d, and mercury of $\frac{1}{55}$th.

The determination of the coefficient of absolute expansion of mercury, is a matter of extreme importance in natural philosophy. Dulong and Petit made a series of very elaborate determinations, and found that the mean coefficient between 0° and 100° C. is $\frac{1}{5550}$, between 100° C. and 200° C. $\frac{1}{5425}$, and between 200° C. and 300° C. $\frac{1}{5300}$. Regnault found these same coefficients to be respectively $\frac{1}{5509}$, $\frac{1}{5376}$, $\frac{1}{5216}$. Dulong and Petit found that the expansion of mercury between −36° and 100° C. is almost absolutely uniform. The coefficient of apparent expansion of mercury in glass was found to be $\frac{1}{6480}$. By slightly modifying the process of Dulong and Petit, Regnault made the following determinations of the absolute expansion of mercury. The first column of the following table indicates the temperature from 0 to 350° C. at which temperature mercury boils. The second column gives the total expansion of mercury between 0° and each number of degrees mentioned, thus a volume = 1·000000 at 0° C. will equal a volume of 1·018153 at 100° C., at 200° C., it will be 1·036811, and so on. The third column gives the mean coefficient of expansion for 1° C. between 0° and each number of degrees mentioned, thus for 100° C. it will be ·018153 ÷ 100 = ·00018153; for 200° C. ·036811 ÷ 200 = ·000184055, and so on. The fourth column gives the true coefficient of expansion for 1° C., and in the case of liquids which change their rate of expansion as the temperature increases, it is necessary to distinguish carefully between the *mean* and *true* coefficient of expansion. Dr Balfour Stewart has given the following definition in his excellent *Treatise on Heat*:—"In general language, if we take a quantity of liquid whose volume at 0° C. is equal to unity, then the true coefficient of dilatation of this liquid at any point is the *rate of increase* in volume of the liquid at that point, as the temperature goes on *regularly increasing*. On the other hand, the mean coefficient of dilatation for 1° C. of the liquid between 0° and any point is the mean rate of increase in volume of the liquid between these two points, that is to say, it is the whole expansion divided by the number of degrees included between the two points."

The figures in the fourth column of the Table show us that the true coefficient of expansion of mercury increases with the temperature.

Table of Absolute Expansion of Mercury

Temperature	Volume of mercury equal to unity at 0° C	Mean coefficient of expansion for 1° C	True coefficient of expansion for 1° C
0	1 000000		00017905
10	1 001792	00017925	00017950
20	1 003590	00017951	00018001
30	1 005393	00017976	00018051
40	1 007201	00018002	00018102
50	1 009013	00018027	00018152
60	1 010831	00018052	00018203
70	1 012655	00018078	00018253
80	1 014482	00018102	00018304
90	1 016315	00018128	00018354
100	1 018153	00018153	00018405
110	1 019996	00018178	00018455
120	1 021844	00018203	00018505
130	1 023697	00018228	00018556
140	1 025555	00018254	00018606
150	1 027419	00018279	00018657
160	1 029287	00018304	00018707
170	1 031160	00018329	00018758
180	1 033039	00018355	00018808
190	1 034922	00018380	00018859
200	1 036811	00018405	00018909
210	1 038704	00018430	00018959
220	1 040603	00018456	00019010
230	1 042506	00018481	00019061
240	1 044415	00018506	00019111
250	1 046329	00018531	00019161
260	1 048247	00018557	00019212
270	1 050171	00018582	00019262
280	1 052100	00018607	00019313
290	1 054034	00018632	00019363
300	1 055973	00018658	00019413
310	1 057917	00018683	00019464
320	1 059866	00018708	00019515
330	1 061820	00018733	00019565
340	1 063778	00018758	00019616
350	1 065743	00018784	00019666

Water presents a curious exception to the general laws of expansion by heat and contraction by cold, for after cooling to 39 2° F (4° C), and suffering diminution of volume, it commences to expand on further cooling For a detailed account of this phenomenon and its results see *Maximum Density of Water* The metal bismuth also expands on cooling According to Erman an alloy of 2 parts bismuth with 1 part of lead and 1 part of tin, expands when heated from 0° to 44° C and then contracts, so that its density at 56° C is the same as at 0°, while at its fusing point (94° C) it possesses the same density as at 44°

3 *Expansion of Gases* In gases we have a physical condition entirely different from that which solids and liquids possess, for while the molecules of the two latter exercise a greater or less amount of cohesive force, the molecules of gases are entirely devoid of this force, they are absolutely unrestrained, and are separated from each other to such an extent that they are beyond the range of the force of cohesion of contiguous molecules We should hence imagine that heat would act more equably upon gaseous bodies than upon solids and liquids, and further that for a given amount of heat the coefficient of expansion of gases would be greater than that of liquids and solids This is indeed the case, gases not only expand far more for an equal increment of heat than liquids and solids, but the expansion is nearly uniform for all gases By the employment of an air thermometer of known capacity, and noting the changes of volume undergone by the air within it, under varied conditions of temperature, Guy-Lussac arrived at the conclusion that the coefficient of expansion of all gases was 0 00375 between 0° and 100° C for 1° C, and that the coefficient is independent of the pressure to which the gas is submitted Regnault has, however, found that there is a slight difference between the coefficients of expansion of permanent gases, and a very perceptible difference in the case of gases which are more or less readily condensable he has further ascertained the fact that the coefficient of expansion increases with the pressure to which the gas is submitted The following are some of his results —

COEFFICIENTS OF EXPANSION FOR 1° C OF VARIOUS GASES

Name of Gas	Under a Constant Volume	Under a Constant Pressure
Air,	·003665	·003670
Nitrogen,	·003668	
Hydrogen,	·003667	·003661
Carbonic Oxide,	·003667	·003669
Carbonic Acid,	·003688	·003710
Protoxide of Nitrogen,	·003676	·003720
Cyanogen,	·003829	·003877
Sulphurous Acid,	·003843	·003903

Now $\frac{3665}{1000000} = \frac{1}{272.85}$ Hence a gas expands $\frac{1}{272.85}$ of its volume for 1° C The fraction $\frac{11}{3000}$ is sometimes used, but more generally $\frac{1}{273}$, and in the case of Fahrenheit degrees a gas expands $\frac{1}{490}$th of its volume for 1° F In other words, if we have a volume of gas at 0° C, and heat it to 273° C, it will double its volume, and if it be at 32° F, and we heat it to 490 + 32° F = 522° F, it will also double its volume, and if it be raised to (490 × 2) + 32° F = 1012° F, it will treble its volume, and so on The following table shows the change of volume which a gas undergoes when submitted to various changes of temperature under a constant pressure The volume at 32° F being = 1000·0 —

Temp	Vol	Temp	Vol	Temp	Vol	Temp	Vol
−50° F	832·7	34° F	1004·1	110° F	1159·2	210° F	1363·3
−45	842·8	35	1006·1	115	1169·4	215	1373·5
−40	853·1	36	1008·2	120	1179·6	220	1383·7
−35	863·3	37	1010·2	125	1189·8	230	1404·1
−30	873·5	38	1012·2	130	1200·0	240	1424·5
−25	883·7	39	1014·3	135	1210·2	250	1444·9
−20	893·9	40	1016·3	140	1220·4	260	1465·3
−15	904·1	45	1026·5	145	1230·6	270	1485·7
−10	914·3	50	1036·7	150	1240·8	280	1506·1
−5	924·5	55	1046·9	155	1251·0	290	1526·5
0	934·7	60	1057·1	160	1261·2	300	1546·9
5	944·9	65	1067·3	165	1271·4	400	1751·0
10	955·1	70	1077·6	170	1281·6	500	1955·1
15	965·3	75	1087·8	175	1291·8	600	2159·2
20	975·5	80	1098·0	180	1302·0	700	2363·3
25	985·7	85	1108·2	185	1312·2	800	2567·3
30	995·9	90	1118·4	190	1322·4	900	2771·4
31	998·0	95	1128·6	195	1332·6	1000	2975·5
32	1000·0	100	1138·8	200	1342·9	1100	3179·6
33	1002·0	105	1149·0	205	1353·1	1200	3383·7

EXPANSIVE FORCE OF ICE See *Maximum Density of Water*

EXTERNAL WORK OF EXPANDING MATTER See *Internal Work of a Mass of Matter*

EXTRA CURRENT See *Current, Extra*

EXTRAORDINARY RAY OF LIGHT See *Ordinary and Extraordinary Ray of Light*

EXTERIOR PLANET A planet whose orbit round the sun lies outside that of the earth

EYE (A.-S, *eage*, Goth, *augo*, Ger, *auge*, Slav, *oko*, Gr, *οκος*, L, *oculus*, Fr, *oeil*, Sans, *akshi*) The human eye may be likened to a camera obscura The body of it is a nearly perfect sphere about nine-tenths of an inch in diameter, there being at the front part a slight projection of a tough transparent membrane, called the cornea The globe of the eye consists of the following membranes—the *sclerotic coat*, the *conjunctiva*, the *choroid coat* the *ciliary body*, the *cornea*, *Jacob's membrane*, the *hyaloid membrane*, and the *retina* At the back of the ball about a tenth of an inch on the inner side of the axis, the optic nerve enters The sclerotic coat is the outer covering of all, constituting the white of the eye, to it are attached the muscles, which move the eye-ball in different directions, it extends in front to the *cornea*, which fits into it as a watch glass fits into its frame The *choroid coat* forms the inner lining of the *sclerotic*, and is covered with an opaque black pigment (*Pigmentum Nigrum*) On this lies the innermost coating of all, the *retina*, which is a delicate reticulated surface formed of an expansion of the optic nerve The *conjunctiva* is a mucous membrane covering the *cornea*, the front part of the *sclerotic*, and turning back over the inner surface of the eyelids The *ciliary body* or process

suspends the *crystalline lens* in its place, forming a bond of union between the *choroid, sclerotic*, and *iris*. *Jacob's membrane* separates the choroid coat and the retina. That which may be termed the optical part of the eye lies in front of it, and immediately behind the *cornea*; this forms the first refracting surface through which the rays of light pass; behind this, if we look into the eye from the front, we see a flat circular membrane of irregular structure called the *iris*. This is usually gray, blue, black, or brown, and has a circular hole in the centre called the *pupil*, which is intensely black. The iris expands or contracts round this central aperture, so as to regulate the quantity of light which enters the eye. Behind the iris is situated the *crystalline lens*, which refracts the light to a focus on the retina. The space between the *cornea* and the *iris* is filled with the *aqueous humour*, the *crystalline lens* contains the *crystalline humour*, and the portion between the *lens* and *retina* contains the *vitreous humour*, which fills up the greater portion of the eyeball; it is contained in convoluted folds of the hyaloid membrane. The *cornea* and *crystalline lens* act as an ordinary convex lens, and form on the retina an inverted image of any object which may be in front. The *spherical aberration* is corrected by having the refractive power of the crystalline lens greatest near the centre, and diminishing towards the circumference. There is, however, no complete correction for colour, but the want of achromatism does not introduce sufficient indistinctness to be noticeable; probably a partial correction is effected by the different dispersive powers of the different media. The whole of the retina appears to be sensitive to light; but of the way in which sensation of distinct vision is produced, nothing is known, our knowledge ending with the picture thrown upon the retina. That portion of the retina where the optic nerve enters is insensitive to light; this spot of no vision may be discovered in the following manner:—Place two dark wafers about four inches apart on a sheet of white paper. Look vertically down upon the right one with the left eye (or *vice versa*) held exactly over it about fifteen inches above the paper; the left wafer will be visible when the eye is directed to any portion of the paper near the right wafer, but will disappear if the right wafer be steadily looked at. Adjustment for distinct vision is effected by alteration of the curvature of the anterior portion of the crystalline lens by the contraction of the ciliary process; in perfect sight the image formed by the lens comes to an exact focus on the retina, the adjustment just named being sufficient for all variations of distance of the object from a few inches up to infinity. Imperfections in this respect give rise to *long-sightedness* or *short-sightedness*, which see.

EYE, ACCOMMODATION OF, TO DIFFERENT DISTANCES. This is effected by an alteration of the shape of the crystalline lens by the ciliary process. (See *Eye*.)

EYE, DURATION OF IMPRESSION OF LIGHT ON THE RETINA. See *Persistence of Visual Impressions*.

EYE, REFRACTIVE POWERS OF PARTS OF. Sir David Brewster gives the following as the refractive powers of the different humours of the eye, the ray of light being incident upon them from air. Aqueous humour, 1·336. Crystalline lens, surface, 1·3767; centre, 1·3990; mean, 1·3839; vitreous humour, 1·3394. (See also *Eye*.)

EYE PIECE. An eye piece is in principle a simple magnifier adapted to microscopes, telescopes, and similar instruments, which is applied close to the eye, and enables the observer to obtain a distinct view of the image formed in the focus of the object glass. The image is magnified a few diameters at the same time. There are various forms of eye-pieces. (See *Terrestrial* or *Erecting Eye Piece, Micrometer Eye-Piece, Negative* or *Huyghens's Eye Piece, Positive* or *Ramsden's Eye-Piece, Pancratic Eye Piece, Kellner's Eye-Piece, Transit Eye-Piece.* See also *Telescope* and *Microscope*.)

F

FACULÆ. (*Facula*, a small torch.) See *Sun*.

FAHL ORE. See *Copper*.

FAHRENHEIT SCALE. See *Thermometer*.

FALLING BODIES. The fall of bodies to the earth in various circumstances offers remarkable illustrations of motion caused by a force producing a uniform acceleration. When bodies of different material fall through the air, they do not usually pass through the same spaces in the same time. A ball of lead and a scrap of paper fall with very different velocities. The difference arises from the resistance of the air, which varies with the form and dimensions of the body, and with the velocity. If, however, the bodies are made to fall in a tube from which the air has been exhausted, then the time of descent and the velocity acquired will be the same. The motion of all bodies *in vacuo* is uniformly accelerated. The force producing the motion is usually called "gravity," and the acceleration is indicated by g. This acceleration is not absolutely the same at all points on the earth's surface; it increases with the latitude

of the place, and decreases with the height above the sea In London a velocity of nearly 32·2 feet is added in every second of time, or $g = 32{\cdot}2$ ft or 32 feet nearly

The chief laws of falling bodies are as follows —When the body starts from rest the space passed through in the first second is $\frac{1}{2}g$ or 16 ft nearly The spaces in successive seconds are as the odd numbers, 1, 3, 5, 7, &c , the spaces from the commencement are as the squares of the consecutive numbers, 1, 4, 9, 16, &c Hence, to find the space passed through in a particular second, we multiply 16 ft by the corresponding odd number , and, to find the space from the commencement, we multiply 16 ft by the square of the number of seconds The velocity at any point is found by multiplying g by the number of seconds from rest When a body is projected vertically upwards with a certain velocity, it rises for a number of seconds found by dividing this velocity by g, and to a height found by dividing the square of the velocity by $2g$, it falls to the ground in the same time as it took to ascend, and strikes the ground with the velocity at starting

FALLING STARS See *Meteors*

FATA MORGANA A phenomenon of unusual refraction seen in the Straits of Messina Under certain conditions of light a spectator sees, upon the Sea of Reggio, a series of pilasters, arches, castles, lofty towers palaces with balconies and windows, villages, and trees, plains with herds and flocks, armies on foot and on horseback, all passing rapidly in succession over the surface (See *Mirage*, *Refraction, Unusual*)

FATTY ACIDS, SERIES OF The homologous series of fatty acids are formed from the homologous series of alcohols by removal of hydrogen and addition of oxygen The following members of this series are known —

Formic acid,	CH_2O_2	Rutic,	$C_{10}H_{20}O_2$
Acetic acid,	$C_2H_4O_2$	Lauric,	$C_{12}H_{24}O_2$
Propionic acid,	$C_3H_6O_2$	Myristic,	$C_{14}H_{28}O_2$
Butyric acid,	$C_4H_8O_2$	Palmitic,	$C_{16}H_{32}O_2$
Valeric acid,	$C_5H_{10}O_2$	Stearic,	$C_{18}H_{36}O_2$
Caproic acid,	$C_6H_{12}O_2$	Arachidic,	$C_{20}H_{40}O_2$
Œnanthylic acid,	$C_7H_{14}O_2$	Cerotic,	$C_{27}H_{54}O_2$
Caprylic acid,	$C_8H_{16}O_2$	Melissic,	$C_{30}H_{60}O_2$
Pelargonic acid,	$C_9H_{18}O_2$		

The acids of this group exhibit well defined properties , as their complexity of composition increases their boiling point rises, and their acid properties decrease They are all volatile, and exhibit a regular increase of boiling point Another homologous series of fatty acids is that of the Oleic series, of which the following are the principal members —

Acrylic acid,	$C_3H_4O_2$	Hypogæic acid,	$C_{16}H_{30}O_2$
Crotonic acid,	$C_4H_6O_2$	Oleic acid,	$C_{18}H_{34}O_2$
Angelic acid,	$C_5H_8O_2$	Doeglic acid,	$C_{19}H_{36}O_2$
Pyroterebic acid,	$C_6H_{10}O_2$	Erucic acid,	$C_{22}H_{42}O_2$
Moringic acid,	$C_{15}H_{28}O_2$		

There are other series of fatty acids which are, however, not well defined

FATTY GROUPS HOMOLOGOUS According to Dr Odling —

	Primary Terms		Secondary Terms	
Formic Family	CH_4	Methene		
	CH_4O	Methylic alcohol		
	CH_2O	Formic aldehyd (?)		
	CH_2O_2	Formic acid		
	CH_2O_3	Carbonic acid		
Acetic Family	C_2H_6	Ethene	C_2H_4	Ethylene
	C_2H_6O	Alcohol	C_2H_4O	Elaylic alcohol
	$C_2H_6O_2$	Glycol		
	C_2H_4O	Aldehyd		
	$C_2H_4O_2$	Acetic acid		
	$C_2H_4O_3$	Glycolic acid		
	$C_2H_2O_4$	Glyoxylic acid		
	$C_2H_2O_4$	Oxalic acid		

	Primary Terms		Secondary Terms	
Propionic Family.	C_3H_8	Propene	C_3H_6	Propylene
	C_3H_8O	Propylic alcohol	C_3H_6O	Allylic alcohol
	$C_3H_8O_2$	Propylic glycol	—	
	$C_3H_8O_3$	Glycerin	—	
	C_3H_6O	Propionic aldehyd	C_3H_4O	Acrolic aldehyd
	$C_3H_6O_2$	Propionic acid	$C_3H_4O_2$	Acrolic acid
	$C_3H_6O_3$	Lactic acid	$C_3H_4O_3$	Pyruvic acid
	$C_3H_6O_4$	Glyceric acid	—	
	$C_3H_4O_4$	Malonic acid	—	
	$C_3H_4O_5$	Tartronic acid	$C_3H_2O_5$	Mesoxalic acid
Butyric Family	C_4H_{10}	Butene	C_4H_8	Butylene
	$C_4H_{10}O$	Butylic alcohol	—	
	$C_4H_{10}O_2$	Butylic glycol	—	
	C_4H_8O	Butyric aldehyd	—	
	$C_4H_8O_2$	Butyric acid	$C_4H_6O_2$	Crotonic acid
	$C_4H_8O_3$	Butilactic acid	—	
	$C_4H_6O_4$	Succinic acid	$C_4H_4O_4$	Fumaric acid
	$C_4H_6O_5$	Malic acid	$C_4H_4O_5$	Metatartric acid
	$C_4H_6O_6$	Tartaric acid	—	
Valeric Family	C_5H_{12}	Luplone	C_5H_{10}	Amylene
	$C_5H_{12}O$	Amylic alcohol	—	
	$C_5H_{12}O_2$	Amylic glycol	—	
	$C_5H_{10}O$	Valeric aldehyd	C_5H_8O	Angelic aldehyd
	$C_5H_{10}O_2$	Valeric acid	$C_5H_8O_2$	Angelic acid
	$C_5H_{10}O_3$	Phocic acid	—	
	$C_5H_8O_4$	Pyrotartric acid	$C_5H_6O_4$	Itaconic acid
Caproic Family.	C_6H_{14}	Caprene	C_6H_{12}	Caprovlene
	$C_6H_{14}O$	Hexylic alcohol	—	
	$C_6H_{12}O_2$	Caproic acid	$C_6H_{10}O_2$	Pyrotrebic acid
	$C_6H_{12}O_3$	Leucic acid	—	
			—	
	$C_6H_{10}O_4$	Adipic acid	—	
			$C_6H_8O_7$	Citric acid
	$C_6H_{10}O_8$	Mucic acid	—	

FAYE'S COMET A comet of short period, discovered by M Faye on November 22, 1843 Leverrier has shown that it came into our system as far back as the year 1747, when the attraction of Jupiter caused it to follow its present track (See *Comet*)

FERRIC OXIDE See *Iron*

FERROCYANIDE OF POTASSIUM A compound of potassium with the hypothetical radical ferrocyanogen (See *Cyanogen*, *Cyanide of Potassium*) It crystallises in large truncated pyramids belonging to the dimetric system, which are of a beautiful amber yellow colour Formula, $K_4Fe_2Cy_6+3H_2O$ It is readily soluble in water When fused at a red heat it decomposes into cyanide of potassium and carbide of iron Its solution, added to ferric salts, forms ferrocyanide of iron or Prussian blue (See *Prussian Blue*)

FERROUS OXIDE See *Iron Oxides*

FIBRES, COLOURS OF MINUTE When a luminous body is viewed through a quantity of minute fibres, such as those of silk, it is seen to be surrounded by a ring of colours, which are due to the interference of the waves of light (See *Colours of Grooved Surfaces*, *Colours of Thin Plates*, *Interference of Light*)

FIBRES, DISCRIMINATION OF MIXED At the Liverpool meeting of the British Association, held in September 1870, Mr Spiller announced the discovery that silk alone of all fabrics usually employed in the manufacture of textile fabrics is completely soluble in strong hydrochloric acid. By immersing fabrics made of mixed silk and other fabrics in concentrated

hydrochloric acid, the silk is entirely dissolved, whilst the cotton, wool, flax, or jute are left intact after the acid is washed away To detect the presence of wool in the residuary fibres picric acid may be employed, which dyes the wool yellow, but has no tinctorial action on cotton or flax The hydrochloric solution of silk has been successfully employed by Mr Spiller in photography

FIELD, MAGNETIC, OR FIELD OF MAGNETIC FORCE A term introduced by Faraday to denote any space through which a magnet diffuses its influence The properties of the magnetic field have been mathematically investigated by Professor J Clerk Maxwell (Cambridge Philosophical Transactions, 1857, "On Faraday's Lines of Force") The conception of a field of magnetic force is of great advantage, and is most appropriate, since it is possible to have a space possessing magnetic properties without the presence of a magnet Thus, a space possessing these properties is produced in the vicinity of a conductor transmitting an electric current (See *Electro-Dynamics*)

In order to express the properties of a magnetic field, it is necessary to specify the direction and intensity of the force at every point in it Faraday has shown how these properties can be experimentally investigated (See *Experimental Researches*)

If a very short magnetic needle were delicately suspended, so as to be capable of turning in any direction about its centre of gravity, and if it were carried from point to point of the magnetic field it would indicate by its direction the direction of the force at each point If such a needle were carried from a certain point *always in the direction in which it points*, it would trace out a certain line, which Faraday calls a *line of force through that point* * Faraday therefore conceived a magnetic field to be traversed by these lines of force which indicate the direction of magnetic attraction at each point, and Maxwell has shown that, by drawing the line of force [illegible], "we may indicate the intensity of the force at any point as well as its direction If in any part of their course the number of lines passing through unit of area is proportional to the intensity there the same proportion between the number of lines in unit of area and the intensity will hold good in every part of the course of the lines All that we have to do, therefore, is to space out the line in any part of their course so that the number of lines which start from unit of area is equal to the number representing the intensity of the field there The intensity at any other part of the field will then be measured by the number of lines which pass through its units of area there, each line indicates a constant and equal force"

A "uniform field of force" is one in which the lines of force are straight, parallel, and equidistant Any place on the earth's surface unaffected by the presence of magnetic matter in the neighbourhood will be a uniform field of force, and the direction of the force will be that of the dipping needle at the place Faraday shows (*Exp Researches*, ser xxix, § 2465,) how to obtain from artificial magnets, with properly shaped poles, an artificial field of uniform force

The term "unit field" is also used by mathematicians A unit field or a field of unit intensity, is produced at unit distance from a pole of unit strength, or it may be described as a field in which a unit pole will experience unit force

FILMS, COLOURS See *Thin Plates, Colours of*

FIRE DAMP See *Marsh Gas*

FIGURE OF THE EARTH See *Earth*

FIRE BALLS See *Meteors, Luminous*

FIRE ENGINE The principle of this may be regarded as combined of the principles of the suction and forcing pumps (See *Suction and Forcing Pump*) For, on the one hand, the effective cylinder is usually some distance above the source of the water, on the other the water has to be forced a considerable distance above the working cylinder When the water has to be raised before being projected, a hose is employed which is capable of resisting considerable atmospheric pressure This is fastened to a tube in communication with the bottom of a cylinder the junction being closed by a valve opening into the cylinder Another opening at the bottom of the cylinder is closed by a valve which opens into a tube leading into the bottom of an "air chamber," that is, a strong chest partly full of air and completely closed with the exception of the end of a tube which reaches below the surface of the liquid, and to which the delivery hose with its nozzle is attached On raising the solid piston, the atmospheric pressure forces the air to ascend into the cylinder through the valve which opens into it (unless the length of the cylinder above the level of the water exceeds 32 feet), on forcing the piston down this valve closes, and the water beneath the piston is urged through the second valve (opening outwards) towards the air chamber It enters this, and the corresponding amount of liquid is not forced out, because the air in the air chest above the surface of the water is, in the first

* Properly defined, a line of force is "a line drawn from any origin so that at every point of its length its tangent is the direction of the attraction at that point" Thomson and Tait, Natural Philosophy, vol i, which also see for mathematical results

instance compressed. The air acts therefore as a compressed spring, and gradually delivers the water through the delivery hose in a continuous stream. In fact, the air acts as a fly-wheel to accumulate force. By this means the sudden straining due to the propulsion of a long column of liquid is avoided, and the fireman is enabled to take surer aim. It is nearly the universal practice to employ two conjugate cylinders, the water from which is forced into the same air chamber, and which are arranged in such a manner that while the one is being forced down the other is being raised. This arrangement completes the continuity of the discharge.

FIRE FLIES, EXAMINATION OF THE LIGHT FROM. The cucuyos or fire-flies (*elater noctilucus*) are coleopterous insects very common in Mexico, where the ladies use them as ornaments for head-dresses, &c. Some were exhibited at the French Academy of Sciences in September 1865, when M. Pasteur read a paper on the properties of their phosphorescent light. The light emitted by these insects is so intense that one of them is sufficient to enable a person to read in the dark at a short distance from it. Examined in the spectroscope the light gives a continuous spectrum, very beautiful but without lines. M. Pasteur has made the same observation with the light of glow-worms. (See *Spectrum, Spectrum Analysis, Spectroscope*.)

FIRMAMENT (*Firmamentum*, a support.) In the astronomy of the ancients, the sphere of the fixed stars.

FIXED LINES OF THE SPECTRUM. See *Fraunhofer's Lines*.

FIXED OILS. See *Oil*.

FIXED STARS. See *Stars*.

FLAME, LUMINOSITY OF. (*Flamma*, for *flagma*, from *flagro*, to burn; φλεγ, Sans. *bhrag*, to shine.) Within the last few years it has been the general opinion that the luminosity of flame is due to the presence in it of solid particles (in most cases carbon) raised to incandescence by the intense heat of combustion. Many experiments support this view: thus it is known that the hydro-carbons which exist in coal gas are decomposed at a high temperature with separation of carbon, and if finely divided carbon is shaken or blown into a non-luminous hydrogen flame it is rendered incandescent, and the flame emits light of the same character as that from an ordinary gas flame. Again, if hydrogen gas is passed through chloro-chromic acid and then ignited, a flame is produced, the luminosity of which is evidently due to the presence of incandescent particles of sesquioxide of chromium. In an ordinary gas flame the presence of free carbon particles is shown by depressing into it a cold substance, which will immediately be covered with soot, or by burning it with an insufficient supply of air, when the carbon becomes evident in the form of smoke. Another argument which has been brought forward to prove that the luminosity is due to incandescent solid matter, is that the spectrum of the light is continuous. These strong arguments have been combated by Dr. Frankland, and although the writer does not consider that it has been shown that the presence of solid particles is not frequently the cause of luminosity, he has certainly proved that flames which are non-luminous under ordinary circumstances become so when combustion takes place at a pressure above that of the atmosphere. Dr. Frankland shows that mixtures of oxygen and hydrogen, carbonic oxide and oxygen, and hydrogen and chlorine, when burnt in close vessels so as to prevent expansion, give very luminous flames, and he also adduces the cases of metallic arsenic in oxygen, of bisulphide of carbon in oxygen, of bisulphide of carbon in nitric oxide, of sulphur in oxygen, of phosphorus in oxygen, as instances in which high luminosity is produced without the presence of solid or liquid particles, and he also shows that many of these luminous flames give continuous spectra, thus upsetting the argument adduced from the continuous spectrum of coal-gas flame. In the above cases the increase of luminosity may be supposed to be due to the enormous increase of temperature, but Dr. Frankland has also shown that pressure has much to do with the luminosity of flame. Candles burning at a diminished atmospheric pressure, such as at the top of Mont Blanc, burn at exactly the same rate as they do at the foot of the mountain, but the luminosity at the summit is reduced from 100 to 18.4 (Phil. Trans. 1861, p. 631). By continuing the experiments at high pressure, it is found that flames which are ordinarily non-luminous become luminous; thus a spirit lamp becomes powerfully luminous in air at a pressure of four atmospheres, and burns with a smoky flame at higher pressures. Dr. Frankland gives in the following table the results of a series of experiments with a coal gas flame burnt under different pressures.

Pressure of Air in Inches of Mercury	Observed Illuminating Power	Pressure of Air in Inches of Mercury	Observed Illuminating Power
30.2	100.0	18.2	37.4
28.2	91.4	16.2	29.4
26.2	80.6	14.2	19.8
24.2	73.0	12.2	12.5
22.2	61.4	10.2	3.0
20.2	47.8		

In a more recent communication to the Royal Society, Dr Frankland has described the extension of these experiments to the combustion of jets of hydrogen and carbonic oxide in oxygen under a pressure gradually increasing to twenty atmospheres These experiments were made in a strong wrought iron vessel furnished with a thick glass plate of sufficient size to permit of the optical examination of the flame The appearance of a jet of hydrogen burning in oxygen under the ordinary atmospheric pressure is well known On increasing the pressure to two atmospheres, the previously feeble luminosity is very markedly augmented, whilst at ten atmospheres' pressure the light emitted by a jet about one inch long is amply sufficient to enable the observer to read a newspaper at a distance of two feet from the flame, and this without any reflecting surface behind the flame Examined by the spectroscope, the spectrum of this flame is bright and perfectly continuous from red to violet With a higher initial luminosity, the flame of carbonic oxide in oxygen becomes much more luminous at a pressure of ten atmospheres, than a flame of hydrogen of the same size and burning under the same pressure The spectrum of carbonic oxide burning in oxygen, under a pressure of fourteen atmospheres, is very brilliant and perfectly continuous If it be true that dense gases emit more light than rare ones when ignited, the passage of the electric spark through different gases ought to produce an amount of light varying with the density of the gas, and Dr Frankland has shown that electric sparks, passed, as nearly as possible under similar conditions, through hydrogen, oxygen, chlorine, and sulphurous anhydride, emit light, the intensity of which is very slight in the case of hydrogen, considerable in that of oxygen, and very great in the case of chlorine and sulphurous anhydride On passing a stream of induction sparks through the gas standing over liquefied sulphurous anhydride in a strong tube at the ordinary temperature, when a pressure of about three atmospheres was exerted by the gas, a very brilliant light was obtained A stream of induction sparks was passed through air confined in a glass tube connected with a condensing syringe, and the pressure of the air being then augmented to two or three atmospheres, a very marked increase in the luminosity of the sparks was observed, whilst on allowing the condensed air to escape, the phenomenon was reversed

FLAMES, SENSITIVE See *Sensitive Flames*

FLAMES, SPECTRA OF See *Spectrum Analysis*, *Elements, Spectra of the*, *Metallic Spectra*

FLEXIBILITY (*Flexibilitas*, from *flecto*, *flexum*, to bend) A property by which numerous bodies easily yield to forces tending to change their form, as, for example, when a bar supported at both ends is permanently bent by a force acting at its middle point, and at right angles to its length (See *Brittleness*)

FLINT See *Quartz*

FLORENTINE EXPERIMENT See *Compressibility of Liquids*

FLOATING CURRENT De la Rive, in order to show the motion of a free current in a magnetic field, invented a beautiful little apparatus which goes by this name Below a flat circular piece of cork is attached a small battery, consisting of a plate of zinc and a plate of platinum inserted in a short test tube, which is filled with dilute sulphuric acid, the terminals pass through the cork, and to them can be attached a vertical coil of wire or a small solenoid, and the whole apparatus can be floated on water by the support of the cork A current perfectly free to move is thus obtained For the use of the apparatus see *Electro Dynamics*

FLOW OF LIQUIDS The law according to which liquids flow out of holes in the bottoms or sides of vessels is called Torricelli's law If we conceive a small mass of liquid to fall freely through a tube, starting from a state of rest at the upper end, the velocity it has on reaching the lower end is $\sqrt{2\,g\,l}$ where l is the length of the tube, and g the accelerating force of gravity (= 32 feet per second) This rate is independent of the density of the liquid The same law will hold good for a laterally neighbouring particle, also for one which immediately follows the first mass, and so on, in fact, for a constant stream of contiguous liquid masses That is, a stream of liquid falling freely down a tube, from a state of rest at the top, will, if the supply at the top be constant, flow out at the bottom with the velocity which any falling body would acquire if dropped through the same distance When water flows out of a hole in the bottom of a vessel, we may regard the moving column to be the column immediately above the hole, reaching to the surface of the water, the water surrounding this column acting like the sides of the glass tube above supposed It is true that this column does not slip down without disturbing the neighbouring particles But when once the currents are established, due to the friction of the falling column against the sides, so little force is required to keep them in motion that the above law is found to be approximately verified by experiment, the more nearly so as the flowing liquid more nearly approaches to perfect mobility Thus mercury and water will flow out at nearly the same rate, while oil or glycerine will flow more slowly The quantity of liquid discharged in this way depends, therefore, on the depth (varies as the square root of the

depth), and also, of course, upon the size of the opening It is found experimentally that the quantity flowing out of a hole of twice the area of another, is nearly exactly twice as much

The same law must apply to the rate of flow out of openings in the side of a vessel maintained full of liquid (compare *Lateral Pressure*) Accordingly, if a series of equal holes be opened at equal distances down the side of a cylinder kept perfectly full of water, the rate of flow, and consequently the quantity which flows from each will be proportional to the square roots of the depths of the openings Thus if a pint of water flows out in a minute through the opening 1 inch from the surface, 2 pints will flow from the opening 4 inches from the surface, 3 pints at that 9 inches, 10 pints from that 100 inches below the surface, and so on It is a law (almost self-evident) of falling bodies, that if a body falling through a given space acquires a certain velocity, the same (or another) body when projected vertically upwards with that velocity, will rise to a height exactly equal to that from which it fell in the first instance Accordingly we might expect that if a tube, the end of which is bent vertically upwards, be fastened to a hole in a vessel of water, the velocity acquired by the water, as it came out of the hole, would be sufficient to carry it as a fountain up to the level of the surface of the water in the vessel If the jet of such a fountain be vertical, such is very far from the case, because the water, which has reached its greatest height, falls vertically down, encountering and depressing the rising column This interference is removed by inclining the jet, but even then the jet seldom reaches above $\frac{9}{10}$ of the height of the liquid's surface This is because no liquid is perfectly mobile, and on account of the friction which the liquid exercises upon the sides of the tube, &c

It is clear that each particle, as it issues through an opening in the vertical side of a vessel will be immediately influenced by gravitation which will give to its path the same form as that of a solid projectile, namely a parabola, the axis of which is the vertical side of the vessel The succeeding particles of water will follow the same path, so that the whole stream has a parabolic form The focus of such a parabola is always that point on the axis which is as far beneath the orifice as the surface is above it

The quantity of liquid which is found experimentally to be delivered in a given time through a hole of given size in the thin bottom of a vessel of water of given height is considerably less than that calculated from the above formula, indeed the actual quantity seldom exceeds 60 per cent of the calculated The cause of this is to be sought in the circumstance that the neighbouring particles of water are dragged into the descending current, and having less downward velocity than that current, their inertia has to be overcome Their place has to be supplied by their neighbours and so on, consequently a portion (40 per cent) of the work of the falling water is expended in setting the mass of the liquid in motion Further, since the lower portion of the descending column is moving faster than the higher portions, there is always a tendency in the column to break, a tendency resisted by the pressure of the air which forces the inert neighbouring particles to enter the circumference of the column, and which presses on the water as it issues out If the actual motion of such a column be examined, which can be done by suspending in the water fragments of some substance having the same density, it is found that the centre of the column descends most quickly, and it is only this portion whose velocity is equal or nearly equal to the theoretical velocity It is clear that those portions of the neighbouring water, which join the current near the bottom of the vessel, will have imparted to them a considerable motion towards the axis of the column The momentum of these particles carries them towards the centre, in consequence of which the current immediately below the orifice is contracted into a sort of waist, which is called the *Vena Contracta*, or *Contractio Venæ* A current thus flowing steadily out of a circular orifice gradually tapers in a continuous stream At a certain distance from the opening it appears to flatten out, to contract, to flatten out again, and so on, until it breaks into a series of separately visible drops If the motion of the expanded and contracted portions be followed by the eye, which can be done by viewing them in a revolving mirror, they are seen also to consist of separate drops following one another in such quick succession, that, under ordinary circumstances, they appear to form a continuous stream The alternate bulging out and contraction of the stream is thus seen to be due to the methodical contraction of each drop in a vertical direction, and consequent bulging out in a horizontal one, as the drop passes what appears to be a thickening of the current When the drops pass through what appears to be a thinner portion of the current, they are laterally compressed and vertically elongated

The quantity of water which flows through a circular opening may be materially increased by adding a tube or spout (Fr *ajoutage*) Thus, if a short cylindrical tube be employed as a spout, the quantity of water may be increased up to 80 from 60 per cent of the calculated quantity, provided that the stream is in contact with the inside of the tube throughout This is caused by the adhesion between the solid and liquid which occurs, unless the velocity of the

efflux be very great The *vena contracta* then usually entirely disappears The stream has a constant diameter, and therefore flows with uniform velocity through the spout A still larger delivery of water is effected by employing a conical delivery tube or spout, the narrow end being next to the vessel If the current be made to touch all sides of the spout, there is generally a well-marked space containing air between the *vena contracta* and the spout The water has, of course, the greatest velocity at the narrowest part next to the vessel, and the least at the opening of the tube, so that though the quantity of water which flows out is increased, its velocity is diminished It is the spreading out of the current, after passing the *vena contracta*, which causes the increase in the quantity delivered For the spreading out must tend to produce a vacuum or rarefaction, in consequence of which the air presses with greater force upon the surface of the water in the vessel, while the stream itself is protected from the opposite pressure by the spout That there is rarefaction in the neighbourhood of the *vena contracta* is shown by inserting a vertical tube in this portion of the spout, and letting the other end dip into water The water will be observed to be forced up the tube by atmospheric pressure

Owing to capillary action, a liquid which wets a capillary tube will not flow out of it unless the vertical height of the column is twice that to which the liquid would rise in the tube (See *Capillarity*) If a capillary tube be held horizontally, so that the weight of the liquid in it may be of no effect in producing motion, it requires a certain force to press a given quantity through in a given time This force varies with the diameter and length of the tube, and also with the nature and temperature of the liquid Poisseville, who has examined this subject with care, concludes that the quantity of liquid forced through varies directly with the pressure, inversely with the length of the tube, and directly with the fourth power of the diameter It appears from experiments of Girand that, of all pure liquids, water flows through capillary tubes with the greatest facility, but it is surpassed by solutions of saltpetre Alcohol, under like circumstances, flows at about half the rate of water, and turpentine at a very much slower rate The temperature, however, makes an enormous difference A rise of 108° F from 40° to 148° increases the rate of flow of water threefold A rise of 60° F in the case of turpentine, from 34° F to 94°, makes that liquid flow sixteen times as fast It appears that these results include the increase of flow due to the increased size of the tubes at the higher temperatures But that change of temperature has a great effect independent of this, is seen by the excess of the difference in the rate of flow in turpentine over that of water for a less temperature difference

FLUIDS, ELECTRIC See *Electricity, Theories of*

FLUORESCENCE (From Fluor-spar, *fluo*, to flow) A term used by Professor Stokes in his explanation of the phenomena called by Sir J Herschel *Epipolic Dispersion*, and by Sir D Brewster *Internal Dispersion* By allowing a solar spectrum to fall on a fluorescent substance, such as a solution of sulphate of quinine, a peculiar blue diffused light makes its appearance at the surface of the fluid on which the actinic or ultra violet rays fall (See *Actinism*) On examining this light, Professor Stokes found that it possessed a less refrangibility than the incident rays, and he was therefore led to the discovery of the change of the refrangibility of the rays of light, the highly refrangible actinic rays being degraded into luminous rays of less refrangibility The effect of fluorescence can be seen without having recourse to a spectrum If daylight, or, still better, the highly actinic light of the flames of alcohol, or of sulphur burning in oxygen, are allowed to shine on a fluorescent substance, the phenomenon will be observed in a marked degree The best fluorescent substances are solution of sulphate of quinine, an aqueous infusion of horse-chestnut bark, an alcoholic solution of chlorophyll, tincture of turmeric, alcoholic extract of thorn apple seeds, and uranium glass The colour of the fluorescent light varies with different substances, thus, with quinine or horse-chestnut bark it is blue, with uranium compounds it is greenish blue, with turmeric or thorn apple it is green, and with chlorophyll red If sunlight is allowed to shine on a solution which contains suspended particles, it is diffused in a manner which, at first sight, looks like fluorescence. This, however, is simply due to the light illuminating the suspended particles This is called *False Diffusion* or *False Dispersion*

FLUORINE An element supposed by most chemists to belong to the chlorine group Symbol F Atomic weight, 19 It is a gas, but its properties in the free state are almost unknown, owing to its intense affinities which cause it to unite with almost every substance with which it comes in contact, the most successful attempt at isolating it having been performed in vessels of fluor-spar, which is a fluoride of calcium The most important compounds of fluorine are the hydrogen compound, fluor-hydric acid, or hydro-fluoric acid see *Hydro-fluoric Acid*, and its combination with silicon. (See *Silicon*)

FLUOR SPAR. See *Calcium, Fluoride of.*

FLUOSILICIC ACID See *Silicon*

FLY WHEEL A wheel possessing a very heavy rim, fixed upon the axis of a crank or other convenient part of a machine, so as, by its momentum, to equalise the motion produced by the action of the connecting rod upon the crank It receives momentum from the prime mover when at its positions of greatest advantage, and expends it in keeping up the action of the machine when the rod is at its dead points Consequently, the crank is carried round continually at an approximately uniform rate (See *Crank*)

FOCAL POINT See *Focus*

FOCI CONJUGATE See *Concave Mirror*

FOCUS (*Focus*, from *Foveo*, to heat, literally, a fireplace) In optics, the point where rays converged by a reflecting mirror or a convex lens meet If the sun's rays are employed the greatest concentration of heat and light will be at this point (See *Virtual Focus*, *Conjugate Foci*) It is sometimes called the *real focus*, where rays originally parallel meet is called the *principal focus* (See also *Principal Focus*)

FOCUS, REAL See *Images, Virtual, Real*

FOCUS, VIRTUAL See *Images, Virtual, Real, Virtual Focus*

FOG A cloud resting on or near the surface of the earth

Fogs appear whenever the temperature of the air falls markedly below the dew-point, so that, if any circumstance occurs either, (1) to lower the temperature of the air considerably, or (2) to pour more vapour into the air than it can hold in the form of invisible vapour, a mist or fog—the aggregate of the particles of condensed vapour—makes its appearance Owing to the fact that a fog may be caused in either of these two ways, fogs result from apparently contradictory causes Thus, a river flowing from a cold to a warm region will often be covered with fog, because it is colder than the surrounding air, which, becoming cooled below the dew-point, discharges its moisture in the form of fog, but, again, a river flowing from a warm to a cold region will also often be covered with fog, because it pours more vapour into the air than can be retained in the invisible form

For similar reasons, wherever there is a marked contrast between the temperature of two regions, winds from either to the other will often bring fog Suppose a wind to blow across a warm and then to a cold region —In passing over the warm region it rises in temperature, and thus not only retains its moisture, but can receive more moisture without becoming saturated, but when this wind reaches a colder region, it is lowered in temperature, and if moisture laden will be compelled to discharge a portion of its moisture in cloud or fog, according as it blows high or low On the other hand, a wind blowing from the cold towards the warm region will often produce fogs, for it will lower the temperature of the air over the warm region, and if that air was nearly saturated, it would be unable to retain its moisture in the invisible form

Fogs often appear on mountain slopes The air which blows up the slopes is gradually lowered in temperature, and at length reaches a level where its temperature is lowered below the dew-point, when condensation takes place

The fogs which occur in the winter months in large cities built on rivers are due to cold winds which flow in upon an accumulation of warm moisture laden air After mild weather, with prevalent southerly wind, a steady easterly current almost invariably causes a dense fog to make its appearance, the air being compelled to resign its moisture as the temperature gradually falls (See *Fogs, Radiation*)

FOG, DRY A term applied to extensive clouds of dust, or smoke, or volcanic ashes, resembling in appearance ordinary fog or cloud, but not affecting the hygrometer Sometimes these dry fogs have covered a wide extent of country, or even a whole continent Many of them are referable doubtless to the discharge of enormous quantities of volcanic ashes, but others seem not associable with any such cause The fog of 1783 was one of the most remarkable instances of a dry fog It extended from Norway to Syria, and from England to the Altai Mountains It is said to have tinged all things with a strange blue colour But "the sun at noon," says Gilbert White, "looked as blank and ferruginous as a clouded moon, and shed a rust coloured ferruginous light on the ground and floors of rooms, but was particularly lurid and blood-coloured at rising and setting" In that year there had been many subterranean disturbances in Europe, and, in particular, a tremendous series of earthquakes had upheaved Calabria

FOGS, RADIATION OF On a night favourable to the formation of dew—that is, when the air is calm and clear, and the earth is radiating its heat into space—the air immediately above the ground becomes cold, but, dew being formed, the temperature of the air does not fall considerably below the dew-point (See *Dew* and *Dew-Point*) If the ground slope, however, the cold air flows down to lower levels. This cold air lowers the temperature of the air which it meets, and if that air is saturated a fog or mist is formed Such a fog will tend to increase, because water, being a good radiant, the fog will part quickly with its heat Thus, these fogs have been

seen to rise like an inundation over a wide range of country bounded by grassy slopes which extend to a higher level

FOMALHAUT (Arabic) The star *α* of the constellation Piscis Australis It is an important southern star, usually recorded in maps as of the first magnitude, but estimated by Sir John Herschel as a second magnitude star

FOOD, FUNCTIONS OF In the widest sense the word food may be said to comprehend all things which, when taken into the animal body, contribute to its maintenance or healthy action It would be absurd to apply the term to a mere poison, or to a foreign body such as a button swallowed by accident, but the above definition includes, in addition to the ordinary alimentary substances, mineral salts, oxygen, water, and even quinine and other medicines

In the more limited sense in which the word is generally used, food consists of certain oxidisable solids and liquids of complex constitution which, inasmuch as they all contain carbon, are classed among organic compounds They are divided into two great groups according as they do or do not contain nitrogen —

I Nitrogenous, or flesh-forming elements of food Liebig's "Plastic Elements of Nutrition"

Albumin, Fibrin, Casein, Legumin, Gelatin (?)

II Non-nitrogenous, or heat producing elements Liebig's "Elements of Respiration"

Fats and Oils, Starches, Sugars

With the exception of Gelatin, which occupies a somewhat doubtful position, the nitrogenous elements have for their chief function the repair of the muscular and other tissues (See *Muscular Power*) The non nitrogenous elements appear to act as mere fuel, being burnt in the body to supply the force which it expends as heat and work But it cannot be doubted that inasmuch as the flesh formers are ultimately oxidized in the body, they also contribute to its available force, and are even capable of replacing to a great extent the non nitrogenous elements All the more important articles of food contain one or more members of each group

Frankland (*Phil Mag*, September 1866) has ascertained with great care the calorific value, as burnt in the body, of the most important substances used as food Fats and oils are greatly superior to all other substances as sources of force, one gramme of the fat of beef when oxidized in the body yielding no less than 3841 metre-kilogrammes of force, whereas the dry lean yielded only 2047, and dry bread only 1625 metre kilogrammes Oatmeal and flour appear in the tables as the most economical sources of force It must not, however, be forgotten that in estimating the value of a food, account must be taken of its *flesh-forming*, as well as of its force producing powers, and, moreover, that its usefulness will depend in no slight degree on the ease with which it can be digested

FOOT POUND The term expressing the unit selected in measuring the work done by a mechanical force A foot-pound represents one pound weight raised through a height of one foot, and a force equal to a certain number of foot-pounds, fifty for example, is a force capable of raising fifty pounds through a height of one foot (See *Dynamical Unit*, *Work*)

FORCE (*Fortis*, strong) Any cause which can move a body, change its motion or keep it at rest when other forces are acting upon it In statics force is synonymous with *pressure*, and is measured by comparison with a unit of weight, thus a statical force is usually described as a *pressure of so many pounds* In dynamics a force is that which produces or changes motion, and is measured by the velocity it can impart to a given mass in a given time The force required to produce a given velocity in a given time is found by experiment to vary as the mass of matter moved, and the force required to move a given mass varies as the velocity generated in a given time, hence, by choosing suitable units we may say that the pressure producing motion is equal to the product of the mass moved, and the velocity generated in a second of time The pressure in this case is termed the *moving force* A force which acts continuously on a body so as to accelerate its motion is sometimes termed an *accelerating force*

FORCE, CONSERVATION OF See *Conservation of Energy*

FORCE, ELECTROMOTIVE See *Electromotive Force*

FORCE EXERTED DURING EXPANSION See *Internal Work of a Mass of Matter.*

FORCE, LINES OF See *Lines of Force*

FORCES, PARALLEL See *Composition of Forces*

FORCES, PARALLELOGRAM OF See *Parallelogram of Forces*

FORCES, PARALLELOPIPED OF See *Parallelopiped of Forces.*

FORCES, POLYGON OF See *Polygon of Forces*

FORCES, TRIANGLE OF See *Triangle of Forces*

FORCING PUMP When liquids have to be raised from a depth exceeding 20 or 25 feet the suction pump is not available (See *Suction Pump*) The forcing pump is then employed

This consists of a cylinder or barrel in or on a level with the water which has to be raised. The bottom of this cylinder is provided with two valves, the one opening into the other out of the cylinder, the latter is in the mouth of a tube which reaches up to the height to which the water has to be raised. A piston (without valves) is worked up and down in the cylinder by a rigid rod reaching to the operator. On being pulled up the water enters the cylinder; on being forced down, the water is forced out of the second valve, and is raised in the conducting pipe. At the second up stroke the water is prevented from entering the cylinder by the valve through which it had passed, while a fresh quantity of water enters the cylinder, and so on.

FORESTS, INFLUENCE OF, ON CLIMATE. Forests have an important influence on climate, somewhat resembling in character that produced by the neighbourhood of water. The changes of temperature in a forest take place slowly. Further, evaporation from ground under trees proceeds slowly, because the sun's heat is warded off, and as what vapour rises is generally left undisturbed by winds, forests are regions of abundant moisture, both as respects the soil they cover and the air around them. Hence the summer heat and the winter cold are alike diminished. Also, the low temperature of forest regions causes winds passing over them to part with their moisture, so that such regions are usually rainy.

FORMIC ACID (*Formica*, an ant). A transparent colourless liquid, of a pungent odour, and very corrosive. Specific gravity, 1·23. Boiling point, 98·5° C (209° F). Composition, CH_2O_2. It mixes with water in all proportions, and unites with bases to form salts, which are called *Formiates*. It is the first term of a series of homologous acids formed by the oxidation of the alcohols, acetic acid being the second term. (See *Alcohols, Homologous Substances*.)

FORMULÆ, CHEMICAL. In order to express shortly the composition of chemical compounds a certain symbolic notation is used; certain symbols are grouped together into what is called a *chemical formula*, and with the aid of chemical formulæ the chemical changes which occur when various bodies are put in contact can be conveniently represented by means of *chemical equations*. It is the object of this article to explain briefly the construction and use of chemical formulæ and equations, and especially so far as is necessary to the understanding of those employed throughout this work.

To represent the chemical composition of a substance, letters are used to denote the elements which occur in it. These letters are in general the initials of the English or Latin names of the elements in question; thus H stands for hydrogen, O for oxygen, and K (kalium, *lat.*) for potassium; and two characteristic letters of the name when there are two elements with the same initial; thus C stands for carbon, Cl for chlorine, and Co for cobalt; N denotes nitrogen, and Na (natrium, *lat.*) denotes sodium. A complete list of the elements with their symbols and atomic weights will be found under *Elements, Table of*. In order to symbolise a body composed of several elements the letters denoting these elements are written one following the other in an order depending on custom. Thus, hydrochloric acid (hydrogen and chlorine) is written HCl; and potassic hydrate (potassium, hydrogen, and oxygen) KHO.

But these initial letters are made to express more than this. According to the laws of chemical equivalence (see *Atomic Weight, Atomic Theory*), the elements combine with each other in definite proportions; and if in any given compound one of the elements be, by some chemical change, replaced by another element, a certain definite quantity of the second is always substituted for a given weight of the first. Thus potassic hydrate always contains 39 parts by weight of potassium, one part by weight of hydrogen, and 16 parts by weight of oxygen; and if by any means we can substitute sodium for potassium in the compound, and thus produce sodic hydrate NaHO, 39 parts by weight of potassium are always replaced by 23 parts by weight of sodium. Moreover when two or more elements unite together in more proportions than one, they unite in quantities which are multiples of the weights called their atomic weights. The numbers which we have just been speaking of—viz., 1 for hydrogen, 39 for potassium, 16 for oxygen, and 23 for sodium, are the atomic weights of those bodies respectively; and it is found that all the compounds of potassium with oxygen contain 39 parts by weight of potassium, or a multiple of that number of parts, and 16 parts by weight of oxygen, or a multiple of that number of parts, and so of all other cases of chemical combination. The symbols of the elements are therefore made to represent their atomic weights; thus the combining proportion of hydrogen being the unit, H stands for 1, O for 16, K for 39, Na for 23, Cl for 35·5, and so forth (see the table above referred to for the atomic weights of the other elements); and when we write the symbol KHO for potassic hydrate we mean that the body is composed of potassium, hydrogen, and oxygen combined together in the proportions 39, 1, and 16, by weight respectively. Lastly, in order to represent combination in multiple proportions we write suffixes in connection with the symbol of the elements concerned. Thus K_2O denotes that 2×39 parts by weight of potassium are combined with 16 parts by weight of oxygen. On this principle the oxides of potassium are written thus —

Name	Symbol	Potassium	Oxygen
Potassic Protoxide	K_2O	39×2	16×1
Potassic Dioxide	K_2O_2	39×2	16×2
Potassic Tetroxide	K_2O_4	39×2	16×4

After what we have said a few words will suffice to explain the use of *chemical equations* When we wish to represent a change taking place on the contact of two or more substances, we write on the left hand side of the algebraic sign (=) *equal to*, the symbols of the bodies mixed, and put between them the algebraic sign (+) *plus*, and on the right hand side of the sign of equality we write the symbols of the bodies produced by the reaction with the sign (+) between them Thus the equation—

$$KHO + HCl = KCl + H_2O$$

means that on bringing potassic hydrate (KHO) in contact with a sufficient quantity of hydrochloric acid (HCl) a chemical reaction takes place, whereby potassic chloride (KCl) and water (H_2O) are produced It is to be noticed that, since each of the symbols represents a certain weight of the body for which it stands, the quantities of the various bodies employed in a reaction, and the quantities of the newly formed bodies obtained are represented in the equation * Thus KHO stands for 56, and if we please to make a calculation in pounds, stands for 56 lbs, on that scale HCl represents 36 5 lbs of hydrochloric acid, and the equation affirms that on mixing 56 lbs of potassic hydrate with 36 5 lbs of hydrochloric acid, we shall obtain 74 5 lbs of potassic chloride (for that is the quantity represented on the one pound scale by KCl) and 18 lbs of water

In some cases it is necessary to show that in a reaction several equivalents of one body are mixed with one or more equivalents of another body This is done by writing a large figure before the symbol with which it is to be connected Thus in the equation,

Chlorine		Potassic Hydrate		Potassic Chlorate		Potassic Chloride		Water
6Cl	+	6KHO	=	$KClO_3$	+	5KCl	+	$3H_2O$

the employment of the numbers 6, 5, 3, denotes that in the reaction are concerned those multiples of the bodies with whose symbols they are connected The equation we have just given is sometimes written—

$$3Cl_2 + 6KHO = KClO_3, \&c$$

$3Cl_2$ being used instead of 6Cl upon theoretical considerations, but both mean the same thing

In a few cases the sign (−) *minus* is employed, thus—

$$KClO_3 - O_3 = KCl$$

would mean that, if from potassic chlorate a certain quantity of oxygen be removed, potassic chloride is left, the method of deoxidation not being indicated in the equation

The meaning of accents and of Roman figures written above a symbol (as O″ and C^{iv}) is explained under *Atomicity*

FORNAX (Abbreviated from *Fornax Chemica*, the Chemical Furnace) One of Lacaille's southern constellations

FOUCAULT'S PENDULUM EXPERIMENTS These experiments were designed to prove the rotation of the earth by the variations of the angle between the plane of oscillation of a pendulum, and the plane of the meridian, that is to say, by showing that when a pendulum oscillates freely, it does not apparently maintain the same direction, but that the direction changes at different rates for different latitudes, and that this variation can be accounted for only by supposing the earth to revolve on its axis An idea of such an effect seems to have occurred long ago, and is mentioned in a paper in the *Phil Trans*, 1742, No 468, by the Marquis de Poli, in the course of some observations on the pendulum It appears also (see *Comptes Rendus*, 1851, No 6), that in 1837 Poisson had hinted at such a variation, but supposed it of insensible amount

The experiment depends on two facts, first the deviation from parallelism to itself, of the meridian of any place, during the rotation of the earth The direction of the meridian at any point, if continued in a straight line, will be a tangent to the earth at that point in the same plane as the axis of the earth, and meeting the axis in a point which is more or less distant from the pole according to the position of the place At the equator this tangent line marking the direction of the meridian, will be parallel to the axis, and at the pole perpendicular to the axis

* It should always be borne in mind that the symbols employed represent numbers Much of the too common abuse of chemical notation arises from forgetting this The practice of uniting the symbol of a body in place of its name is highly objectionable We would also protest against the use of such equations as—

$$KClO_3 + Heat = KCl + O_3$$

Explanations ought to be put in words not in equations, and introducing confusion to save space is not advantageous.

In one revolution of the earth, the tangent line will trace out a cone, the developed angle of which will increase as we proceed from the equator to the pole It is easily proved that if we suppose the earth a perfect sphere, this angle varies as the sine of the latitude of the place, being the angle obtained by multiplying 360° by the sine of the latitude, hence the inclination of two successive positions of the meridian of a place to each other after an interval of time may be found by taking the same part of the above angle as the interval is of twenty-four hours

The second fact is the independence of the motion of the pendulum, notwithstanding that the point of support is carried along with the earth in its rotation, and that the whole seems to form a part of the earth This is easily elucidated by very simple experiments, in which the vibration of a small pendulum is seen to continue parallel to itself notwithstanding a motion given to the point of support, the effect being, in fact, only a simple consequence of the co-existence of two motions communicated to a body at the same time

From these two facts, it would appear that, supposing the earth to revolve on its axis, if a pendulum, consisting of a fine flexible wire and a plumb-bob, be suspended from the ceiling of a lofty room, and made to oscillate in one plane, as, for instance, in the plane of the meridian, or exactly north and south, after a short time the direction of oscillation will not be north and south, but will have turned from the north towards the west The meridian will have gone through a certain angle in consequence of the earth's rotation, but the direction of the oscillation will have remained unchanged At the pole the direction of the pendulum would apparently make a complete circuit in 24 hours, while at the equator it would maintain the same direction The experiment originally made by M Foucault, was repeated and confirmed under the inspection of M Arago, and other eminent scientific men, with due precautions, in Paris, as also at Ghent, Brussels, and elsewhere In England, besides the public repetitions at the Royal, London, and Polytechnic Institutions, by Dr Roget, Mr Bishop, Dr Bence Jones, and Mr Bass, the experiment was tried at York by Professor Phillips, and at Bristol by Mr Brent, with careful attention to all the circumstances likely to ensure the avoidance of sources of error, and to secure precise results Other observers have also repeated it in various places, especially at Dublin, where Messrs Haughton and Galbraith of Trinity College pursued the research with all imaginable precautions, and obtained results somewhat different from those of other observers According to nearly all the other experiments, the rate of deviation continued uniform, although the amount of deviation given by different observers varies, according to Messrs Haughton and Galbraith, the rate varied, and they seem to have been the only observers who have watched through a complete revolution, the time of which was observed to be 28 hours, 26 minutes

The rates of deviation for one hour were, at Paris about 11° 30′, at Bristol 11° 42′ at Dublin rather more than 12°, at York about 13° The sources of probable error are very numerous and not easy to guard against Such are the imperfect freedom of suspension, resistance of the air, currents in the air, &c The most formidable, however, is the extreme difficulty, amounting almost to impossibility of causing the pendulum to oscillate in one plane, and of preventing its motion in a narrow ellipse At starting, the bob is usually drawn aside and attached to a fixed point by a fine thread of silk, which is afterwards burnt by a candle

On the whole, although the experiment has been publicly repeated by men of eminence and experience as observers, yet the discrepancies and difficulties connected with the observed results, seem to indicate that the subject has not yet been thoroughly worked out It is of high interest and importance, and merits a revision of the theory and a repetition of the experiments It should, however, be remarked that if fully verified, the result would hardly amount to a more palpable proof of the earth's rotation than other astronomical phenomena afford

FRACTURE (*Frango, fractus,* to break) Any rupture of a solid body by which its strength is impaired Fractures may be classified according to the kind of strain or stress which produces them For instance, a direct pull may produce a tearing or stretching fracture, a compressing force a crushing fracture, a transverse force may produce either shearing, wrenching, or transverse breakage An accurate knowledge of the power of different materials to resist forces tending to produce fracture is exceedingly important to the engineer (See *Strength of Materials*)

FRAUNHOFER'S LINES The black lines which cross a very pure solar spectrum were first observed by Wollaston, but they were afterwards examined with so much care and philosophical refinement by Fraunhofer, that they are generally called after his name They are occasioned by the light from lower portions of the solar surface (which are supposed to give a continuous spectrum), passing through certain incandescent metallic vapours, such as iron, sodium, magnesium, hydrogen, &c, which exist in the upper portions of the luminiferous envelope of the sun, and, in a less degree, through the aqueous vapour and permanent gases of the earth's atmosphere (See *Spectrum, Spectrum Analysis, Metallic Spectra, Spectroscope*)

FRAUNHOFER'S LINES, ARTIFICIAL When a spirit flame containing a sodium

compound is examined in the spectroscope, a bright yellow line is observed, due to the incandescent sodium vapour which emits light of this refrangibility But sodium vapour is also opaque to light of the same refrangibility, and when this vapour is interposed in the path of a beam of light forming a continuous spectrum in the spectroscope, a black line is cut out occupying the position of the luminous line formerly observed, producing, in fact, an artificial Fraunhofer line D By employing other metallic compounds, other lines can be reversed in a similar manner (See *Spectrum Analysis*, *Fraunhofer's Lines*, *Metallic Spectra*, *Spectroscope*)

FREE CHARGE See *Charge, Free*

FREEZING MIXTURES, whose object is the production of artificial cold, take advantage of the heat which is required for the passage of a body from the solid to the liquid condition It is explained (see *Latent Heat*) that for the mere change from the solid to the liquid state a certain quantity of heat is necessary, and is taken up during the change *without increasing the temperature* of the body By mixing together two substances, one, at least, of which is a solid, and which, on mixing, is liquefied, a very low temperature may be produced Heat being required for the liquefaction, the temperature of the mixture falls The following list of freezing mixtures, and of the lowering of temperature due to them, is given by Professor Balfour Stewart —

Substances	Parts by Weight	Reduction of Temperature
Sulphate of sodium, Hydrochloric acid,	8 5	+ 10° C (+ 50° F) to − 17° C (+ 1° F)
Pounded ice or snow, Common salt,	2 1	+ 10° C to − 18° C (0° F)
Sulphate of sodium, Dilute nitric acid,	3 2	+ 10° C to − 19° C (− 2° F)
Sulphate of sodium, Nitrate of ammonium, Dilute nitric acid,	6 5 4	+ 10° C to − 26° C (− 15° F)
Phosphate of sodium, Dilute nitric acid,	9 4	+ 10° C to − 29° C (− 20° F)

For another method of producing artificial cold, see *Refrigerator*

FREEZING POINT, INFLUENCE OF PRESSURE UPON. Professor James Thomson first pointed out that it is a consequence of the dynamical theory of heat that the freezing-point of a substance which expands in solidifying should be lowered, and that of a body which contracts in solidifying should be raised by the application of pressure during the operation of freezing His brother, Sir William Thomson, shortly after experimentally verified the idea in the case of water, and showed that under a pressure of 16 8 atmospheres the temperature of its freezing point was lowered by 0° 232 F, a number which agrees closely with the result calculated theoretically for that pressure—namely, 0° 230

Bunsen afterwards experimented on paraffin and spermaceti, bodies which contract on freezing, and showed, in the case of the latter, a rise in the temperature of the freezing point of 5 7° F for a pressure of 156 atmospheres

Mousson lowered the freezing-point of water 18° C (32° 4 F) by a pressure of 13000 atmospheres

Professor James Thomson applied this result to account for the phenomenon of the "regelation of ice" By pressure a small quantity of ice is liquefied, and the liquefaction gives rise to the disappearance of heat as *latent heat* The adjacent portions of the ice are thus chilled below the freezing-point, and regelation is the result

FRESNEL'S LENS. Fresnel has devised for lighthouse purposes a system of building up, round a central convex lens, large lenses composed of rings of glass so curved, that they all have the same focus The lamp being placed in this focus, the divergent rays are refracted by the compound lens, and rendered parallel (See *Lens*)

FRESNEL'S RHOMB See *Rhomb, Fresnel's*

FRICTION (*Frico*, to rub) That resistance to motion which arises from the roughness of surfaces, the rigidity of cords, and the presence of air or water It is one of the *passive* resistances to motion, (see *Resistance*), preventing the bodies from sliding upon one another, and depending on the force with which the bodies are pressed together The determination of the amount of force required to overcome friction in special cases constitutes one of the most important subjects of practical investigation connected with mechanics

No surfaces are perfectly smooth When a body is laid upon a horizontal surface, even

though the surface be one of polished steel, the application of *some* amount of force is necessary in order to make the body slide. The resistance which this force overcomes is termed friction.

In order to measure friction, the body under consideration is placed on a plane which can be gradually raised from the horizontal position towards the vertical by some mechanical appliance such as a screw. It is found that the inclination of the plane at last reaches an angle such that any further elevation of the plane causes the body to slide. (See *Angle of Repose*.) By this means a measure of friction may be deduced from the general principles of the inclined plane. (See *Inclined Plane*.) When a body rests on a rough inclined plane three forces act upon it, the weight which is vertical, the reaction of the plane perpendicular to the plane, and the force of friction in the direction of the plane. When the plane has reached the limiting angle of repose, the ratio of the force tending to make the body slide to the force pressing it against the plane is called the coefficient of friction. This is the same as the ratio of the height of the plane to its base, or, in other words, is equal to the tangent of the angle of repose.

In the experiment for determining the coefficient of friction, the base taken as one unit is a foot in length, and then the height expressed as the fraction of a foot is the coefficient of friction. This number varies for different surfaces, and can only be obtained by direct experiment. It is always greater for like than for unlike substances.

The result of experiments have established the following laws, of which the first is fundamental:—

I. When the materials composing the surfaces in contact remain the same, the friction is proportional to the pressure. Suppose a block of wood, having a hole bored in it, to rest on a plane inclined at the angle of repose; if lead be poured into the hole, the screw may be turned so as to incline the plane at a greater angle without causing the body to slide. Thus by increasing the pressure we increase the friction.

The closeness with which results of experiment coincide with this law may be seen by the following table from Morin, relating to oak, with fibres perpendicular to one another:—

Extent of surface in contact	Normal Pressure	Pressure tending to produce motion when the body is on the point of moving	Coefficient of friction
0.947 sq. ft.	121 lbs	67 lbs	0.55
	283	151	0.53
	495	252	0.51
	1995	1171	0.58
	2525	1287	0.51
0.043 sq. ft.	389 lbs	204 lbs	0.52
	403	213	0.53
	1461	855	0.52

II. The friction is independent of the extent of the surfaces in contact. The angle of repose is found to remain the same whichever face of the body is placed in contact with the plane. This result may at first appear surprising, but a little reflection will show that it is a natural consequence of the first law; for if, in the second position, the area in contact be five square inches, as compared with forty square inches in the first, each square inch bears eight times the pressure, so that the friction per square inch in the second case is eight times as much as in the first, and the total friction remains the same.

When the pressure per square inch becomes very great, the friction ceases to increase in proportion to the pressure. When the pressure in building constructions is so intense as to crush or indent the substances at or near their surface of contact, the friction increases more rapidly than the pressure; but such a pressure should never be reached in any structure. Surfaces which have been long in contact present a variation in this respect, especially those of substances which may be sensibly indented by moderate pressure, such as timber. When beams of timber are mortised together, and remain at rest, the parts acquire an additional force of adhesion and cohesion, which is not proportional to the pressure (see *Adhesion and Cohesion*); and, as a general law, friction between bodies after remaining relatively at rest is greater than friction between the same bodies in sliding over one another. The excess of this *friction of rest* over the *friction of motion* is, however, easily destroyed by giving a slight vibration to the bodies, so that in considering stability of structures, we need only reckon the friction of motion.

III When the body is in motion, the friction is independent of the velocity The effect of friction is always to resist the motion of a body Hence, if the object of a force be to move a weight, friction opposes the power, but if it be applied to keep a body at rest, a less power will be sufficient than if the surfaces were smooth

Friction is a vast source of loss of power in machinery Usually, at least one third, and often as much as one-half, of the entire moving force employed, is occupied in overcoming friction Although friction in a machine is a disadvantage, it is the source of the efficacy of such instruments as nails, pegs, screws, wedges, &c , for example, when a wedge is driven into a substance by the force of percussion, it would rebound after each blow but for friction Without friction most structures would fall to pieces, it is a necessary condition of all forward motion, grasping, &c , indeed, if there were no friction between the wheel of a locomotive engine and the rail, the progress of the wheel would be impossible for want of the necessary purchase

Friction is frequently utilised when great resistances are required to prevent motion For example, a boat carried in the current of a stream may be easily arrested by making two or three turns of the rope attached to it round a tree or fixed object When one surface slides on another, the resistance is termed *sliding* friction, when one rolls on the other, so that different points in each are brought into contact, it is termed *rolling* friction With the same surfaces and pressure, sliding friction is much greater than rolling friction On this account carriages are supplied with wheels, articles of household furniture with castors, &c, and generally substances are selected for application in rolling friction which have least coefficients of friction, combined with inexpensiveness, for the required purpose When as in descending a steep hill, it is advisable to check the motion of a carriage, the wheel is "locked" by a chain or by a break, so that the friction thereby caused may offer a greater resistance to the motion (See *Break*)

The first full investigation of friction was made by Coulomb, who published a memoir on this subject in 1785, an abstract of which will be found in Young's *Natural Philosophy*, vol ii Mr Moseley pointed out the properties of the angle of repose or limiting angle of resistance, and General Morin investigated very fully the calculations connected with friction (See Morin's *Notions Fondamentales de Mécanique*) The following table show some of his results —

Substances	Angle of Repose	Coefficient of Friction
Oak on oak, fibres parallel, .	$31\frac{1}{2}°$	0 62
" " perpendicular,	$28\frac{1}{2}°$	0 54
Oak on elm " parallel, .	$20\frac{1}{2}°$	0 38
Elm on oak " " . .	$34\frac{1}{2}°$	0 69
Wood on wood, dry, . .	$14°$ to $26\frac{1}{2}°$	0 25 to 0 5
" soaped	$11\frac{1}{2}°$ to $2°$	0 2 to 0 04
Metals on metals, dry, . .	$8\frac{1}{2}°$ to $11\frac{1}{2}°$	0 15 to 0 2
" wet and clean, . .	$16\frac{1}{2}°$	0 3
Metals on oak, dry,	$26\frac{1}{2}°$ to $31°$	0 5 to 0 6
" soapy, ...	$11\frac{1}{2}°$	0 2
Leather on metals, dry, ...	$29\frac{1}{2}°$	0 56
" " wet, ...	$20°$	0 36
" " greasy, . . .	$13°$	0 23
" " oily, .	$8\frac{1}{2}°$	0 15
Smoothest and best greased surfaces, .	$1\frac{1}{4}°$ to $2°$	0 03 to 0 036

FRIGID ZONE See *Arctic Circle*

FRINGES Phenomena observed when the edges of the shadow of a small opaque body, such as a fine wire, thrown by divergent light, are minutely examined They are due to the interference of the waves of light (See *Diffraction*)

FROST The term used to describe the weather, when the temperature descends below 32° Fahrenheit, so that all superficial moisture becomes frozen

FRUIT SUGAR An uncrystallisable mixture of dextrose and lævulose (See *Sugar*)

FUCHSINE See *Aniline*

FULCRUM (*Fulcrum*, a bed-post, from *fulcire*, to prop) The fixed point about which a lever turns The fulcrum either lies between the forces, in which case the forces, if parallel, act in the same direction, and the pressure on the fulcrum is their sum, or it lies on the same side of both forces, in which case the forces act in opposite directions, and the pressure on the fulcrum is their difference When the forces are not parallel, the direction and magnitude of the pressure on the fulcrum must be found by means of the parallelogram of forces That the fulcrum shall be strong enough to bear the pressure upon it is an important condition

of equilibrium which must be borne in mind in applying the lever. This condition is referred to in the famous maxim of Archimedes, "Give me a point of support, and I will move the whole world." (See *Lever*.)

FULMINATING PANE. A very simple form of electric condenser. It consists of a pane of glass having two squares of tinfoil pasted opposite to each other, one on each side. They cover nearly the whole side, leaving only a margin of an inch or so all round. This margin ought to be coated with shell-lac varnish to improve its insulating powers. The pane is set on a wooden frame, and one of the tinfoil coatings is connected with this and with a ring which it carries, and thus, by means of a chain, can be put in communication with the ground. The other is put in connection with the electric machine when it is to be charged. The action is precisely that of the Leyden jar or *Æpinus Condenser*, (*q v*.)

FULMINIC ACID. An acid which is known in combination with bases, as *fulminates*, but which has not hitherto been prepared in the free state. Their formula is $C_2N_2M_2O_2$ (M denoting a metal.) The principal fulminates are *fulminate of mercury* and *fulminate of silver*, commonly known as fulminating mercury and silver. They are prepared by dissolving the respective metal in nitric acid, and adding alcohol, when crystals are deposited on cooling. Fulminating mercury is the principal ingredient in the explosive mixture of percussion caps, and is likewise used for effecting the explosion of gun-cotton. Fulminating silver is seldom employed, owing to the great danger attending its preparation and manipulation.

FUMING. There are certain liquids which, by exposure to the air, fume or emit a visible smoke. Spirit of salt, also known as muriatic or hydrochloric acid, does this. This liquid is a solution of hydrochloric acid gas in water which absorbs it greedily, water at 40° F absorbing 480 times its own bulk of the gas. But water absorbs ammoniacal gas still more greedily; for at 32° F it will take up 1050 times its volume of the gas, and yet the solution, known as *liquor ammoniæ*, does not fume on being exposed to the air. Why is this? Mr Tomlinson has given an answer to this question in the *Chemical News*, xix 23, which we here abridge. If the alkaline solution be heated, the whole of the gas can be driven out of the water at about 160° F, but, on heating the acid solution, it will part with gas until it has a density of 1 10 (at 60°), when it will have a boiling point of 233° F, and will distil unchanged.

Moreover, the alkaline solution is lighter than its own bulk of water; the acid solution is heavier. The presence of the ammonia lowers the boiling point of water; the presence of hydrochloric acid gas has a contrary effect. Hence, the mode of combination between ammonia and water must be different from that between hydrochloric acid and water. The one must be a case of simple adhesion, the other of true chemical combination as well as adhesion.

"Ammonia let out into moist air simply adheres to the moisture, and increases its volume. Vapour of alcohol, ether, &c, does the same. Now any amount of aqueous vapour that the air can maintain in an invisible elastic state, at a given temperature, it can maintain with increased effect in the case of ammonia vapour, alcohol vapour, &c. Hence, the combination of these vapours with the moisture of the air is necessarily an invisible compound.

"Hydrochloric acid gas, on the other hand, let out into the air, combines chemically with the moisture, producing condensation or diminution in bulk. Hence, the compound is visible, just as the condensation of pure steam in air produces visible vapour.

"Fuming nitric acid and Nordhausen sulphuric acid are also cases in point."

FUNDAMENTAL NOTE of a string or organ-pipe, the lowest note the instrument is capable of producing—namely, that produced when the string or the air in the organ pipe vibrates as a whole. (See *Harmonics*.) In music, the principal note of a melody or composition, to which all the others are adapted. In this sense it is commonly called the *key-note* of the composition. The root of a chord is also called the fundamental note of the chord. (See *Harmony*.)

FUSEE, (*fusus*, a spindle; French, *fuseau*), a contrivance for rendering uniform the action of the mainspring in watches and marine timepieces. It consists of a spirally grooved cone, on which a flexible chain can be wound. The chain is fastened by one end to the base of the cone, and by the other to a barrel containing the mainspring. By uncoiling, the mainspring causes the barrel to rotate, so as gradually to draw the chain off the fusee, and, by means of the toothed wheel at its base, to set in motion the remaining wheels of the timepiece. One end of the axis of the fusee is accessible externally, so that at the proper time it may be "wound up." The force of the mainspring decreases as the spring uncoils, but in consequence of the conical shape of the fusee, as the force diminishes, the chain is unwound from a part of gradually increasing diameter. Now, by the laws of the wheel and axle, the greater the radius of the wheel, the less is the required power. Hence, by increasing the diameter of the grooves of the fusee, exactly as the force of the mainspring diminishes, uniformity of motion is secured. (See *Lever*, *Mechanical Advantage*, *Wheel and Axle*; *Variable Motion*, and *Horology*.)

FUSEL OIL A nauseous oily liquid produced in the alcoholic fermentation of potatoes, &c, consisting for the most part of amylic alcohol It communicates a very unpleasant taste and smell to alcohol

FUSING POINT Different substances, when heated, fuse at very different temperatures, which, however, are the same for the same substance, if the external pressure remains constant The temperature at which fusion commences is termed the *fusing point* The following table shows the fusing point of various substances (taken for the most part from Pouillet's *Eléments de Physique Expérimentale*) —

TABLE OF FUSING POINTS.

Names of Substances	Fusing Point in degrees Fahrenheit	Names of Substances	Fusing Point in degrees Fahrenheit
Platinum,	3082°	Iodine,	225°
English wrought iron,	2912	Alloy of 1 part lead, 1 part tin, and 4 parts bismuth,	201
French wrought iron,	2732	Sodium,	197
Steel,	2552	Potassium,	136 4
Manganese (cast),	2282	Phosphorus,	111 5
Gold (pure),	2282	Wax,	142
Copper,	1922	Margaric Acid,	140
Silver (pure),	1832	Spermaceti,	120
Bronze,	1652	Stearine,	117 8
Antimony,	810	Acetic Acid,	113
Zinc,	680	Tallow,	92
Lead,	608	Ice,	32
Bismuth,	512	Bromine,	+ 9 5
Tin,	446	Sulphuric Acid,	—30 0
Alloy of 5 parts tin, 1 part lead,	381	Mercury,	—37 9
Alloy of 1 part tin, 1 part bismuth,	286 2		
Sulphur,	239		

FUSION (*Fundo*, to cause to flow, to render fluid) When solids are heated they continue to rise in temperature until at a certain point fusion commences, and the temperature then ceases to rise until the whole mass has passed from the solid to the liquid condition The temperature at which this takes place is the same for the same substance, so long as the pressure remains constant (See *Fusing Point*) A few solids, among which may be mentioned arsenious acid, and solid carbonic acid, pass at once from the solid to the gaseous condition, that is to say, their point of fusion coincides with their point of vaporization, hence they have no intermediate liquid condition. Other substances soften before fusion, and become more or less viscous, as in the case of glass, sealing-wax, and the metals capable of being welded, such as platinum and iron During fusion all substances absorb a certain amount of heat, called the *latent heat of fusion* or *of liquefaction*, which is expended in forcing asunder the molecules of the substance heated, against their inherent attraction or cohesive power Hence this absorbed heat disappears as heat, and becomes mechanical work, in fact, it is expended in *internal work* (which see), and when the liquid, on cooling, becomes solid again, the heat thus employed reappears as sensible heat The latent heat of fusion of certain substances is given under the heading *Latent Heat* Substances for the most part expand in undergoing fusion, and this we should expect, for one of the most apparent effects of heat upon matter is expansion, that is, a separation of the molecules of a substance to a greater distance than before, in virtue of the additional amount of the motion called heat, which has been communicated to them A few substances, however, do not expand, among them, ice, bismuth, and antimony, which contract when they are fused, and conversely expand when they become solid (See *Maximum Density of Water.*) Pressure exercises considerable influence on the fusing point, substances like water, which expand in solidifying, have their points of fusion lowered by pressure, while substances, which (like the generality) contract in solidifying, have their points of fusion raised by pressure Bunsen found that the fusing point of paraffin with a pressure of 1 atmosphere was 46 3° C, when the pressure was increased to 85 atmospheres, it rose to 48 9° C, while under a pressure of 100 atmospheres, the fusing point was 49 9° C Professor James Thomson predicted, on theoretical grounds, that the fusing point of ice (and other substances which contract on fusing), would be lowered by pressure, and this was proved by Sir W. Thomson By the application of a pressure of 13000 atmospheres (1 atmosphere = 15 lbs on the square inch of surface) Mousson found that the fusing point of ice was lowered from 0° to —18° C

Every substance absorbs a certain definite amount of heat in passing from the solid to the liquid condition, which, as stated above, is consumed in internal work and therefore disappears as sensible heat The large amount of heat absorbed by ice in melting, and given out by water in freezing, has a great influence on the temperature and climate of countries in which water abounds This is discussed in detail in the articles which treat of meteorology

FUSION, LATENT HEAT OF. See *Latent Heat*

GALAXY. (γάλα, milk, ὁ γαλαξίας κύκλος, the milky zone) The *Via Lactea* or *Milky Way* The zone of milky light, which is visible in the sky on a clear night, has from the earliest ages attracted the attention of astronomers The views formed respecting it by some of the earlier observers were *bizarre* and fanciful Thus Theophrastus believed that the celestial hemispheres were knit together incompletely, so that a circle of faint light appeared where spaces had been left through which the fiery heavens can be seen Before him Aristotle had taught that the Milky Way and comets are constituted of the same materials Yet some of the earlier astronomers formed juster views To Democritus has been attributed the theory that the Milky Way consists of a multitude of stars, too small to be separately visible, a theory referred to by Manilius in the often quoted lines in which he asks—

Anne magis densâ stellarum turba coronâ
Contexit flammas et crasso lumine candet
Et fulgore nitet collato clarior orbis?

We owe to Galileo the first discovery of any evidence really bearing on the subject of the Milky Way By resolving portions of the zone into stars he placed the true constitution of the whole beyond all reasonable question, so far as the discreteness of its constituent bodies is concerned Yet it remained to determine what are the relations between the stars forming the Milky Way and those visible to the naked eye Sir William Herschel was the first to attack this noble problem, and we owe to the labours by which he and his son Sir John Herschel have investigated the subject, the principal means we have of forming an opinion respecting the figure of the galaxy Before considering their researches, however, it will be necessary to give a brief account of the appearance and general characteristics of this wonderful zone of milky light We follow the account given by Sir John Herschel

In the northern heavens the Milky Way is for the most part faint From Cepheus over Cassiopeia, Perseus, Auriga, &c, to Monoceros it forms a single stream, save where, in Perseus, it throws out a branch which can be traced as far as Epsilon of that constellation, and probably to the Pleiades and Hyades Beyond Monoceros, southwards, the Milky Way becomes broader, brighter, and more complicated, opening out in Argo into a fan-like expansion some twenty degrees wide Here the continuity of the stream is interrupted, a broad black rift extending right across the Milky Way in this part—one of the widest and brightest be it noticed—of its course Beyond the rift there is another fan like expansion, whose widest part, like that of the other, abuts upon the rift As the Milky Way narrows down towards the head of this expansion, it becomes brighter, and its outline is in places singularly well marked In Crux it expands again, but in the very heart of this expansion there is a large black space, perfectly clear of lucid stars and of milky light This is the Southern Coalsack Passing on towards Scorpio, we find the Milky Way dividing, close by α Centauri, into two branches, of which, however, one only can be traced as a distinct branch for any distance This stream passes northwards over Sagittarius, where it exhibits a singularly rich condensation, over Aquila where there are several such condensations, and thence, rapidly diminishing in brightness, to Cygnus The other branch, so soon as it enters Scorpio, exhibits a multitude of complicated divisions, sub divisions, and detached portions Near Antares it throws a great projection out towards Libra, that is, in a direction nearly at right angles to that of the main stream Another subdivision, passing towards Serpens, seems to seek the main stream, but cannot be traced quite up to it, coming to an end a few degrees to the north of the star Mu Sagittarii Returning to the other stream near Cygnus, we find it proceeding onwards to Cassiopeia, throwing out a projection from Cepheus towards the north pole, while from Cygnus a branch extends southwards, very rich in Cygnus, but rapidly fading in brightness, until it comes to an end on the equator In most star maps this branch is carried southwards beyond the equator to meet the branch which terminates near μ Sagittarii We have Sir John Herschel's authority for asserting that the two branches do not meet

Thus, taking a general view of the Milky Way, we see that the account usually given, accord

ing to which the galaxy forms the complete circuit of the heavens, and is double along one-half of its course, is incorrect in both respects

It is necessary to make a few remarks respecting the relation between the visible stars and the galaxy It is commonly stated that even among the visible stars there is a marked increase of numbers in the neighbourhood of the Milky Way This opinion is founded on a statement made by Sir John Herschel in his Outlines of Astronomy But it is to be remarked that in his great work on the southern heavens he asserts the exact reverse At p 382 of that noble work, he remarks that on a general view of his statistical researches respecting stellar distribution, "it appears that the tendency to greater frequency, or the increase of density in respect of statistical distribution in approaching the Milky Way, is quite imperceptible among stars of a higher magnitude than the 8th, and except on the verge of the Milky Way itself stars of the 8th magnitude can hardly be said to participate in the general law of increase" It is of the utmost importance, if we are to form just views respecting the constitution of the Milky Way, that this discrepancy and the interpretation of its existence should be rightly understood As a matter of fact the visible stars *are* associated with the Milky Way as Sir John Herschel remarks in his Outlines, but the association is of a peculiar character, its nature being such that in considering whole zones of stars parallel to the galaxy, all trace of the law of association disappears, and thus the account given in his work on the southern heavens is also justified The lucid stars in fact follow the complexities of figure observed in the galaxy, but show no signs of aggregation towards the zone to which the galactic circle is referable

Now the importance of this fact, which becomes clearly recognisable in well constructed charts of the heavens will become more clearly apparent when we consider Sir William Herschel's researches into the Milky Way, and his interpretation of them

Adopting as the basis of his researches the hypothesis that the stars are distributed with a general uniformity throughout the sidereal system, so that the minute and closely congregated stars seen in the Milky Way are in reality as widely separated as the lucid orbs, he devised a simple plan for gauging the celestial depths It is clear that if the sidereal system have limits and the observer use a telescope powerful enough to reach those limits, he need only turn his telescope successively in different directions, and count the number of stars (of all orders) seen in its field of view, to form a sufficiently exact estimate of the relative extension of the system in those directions Where he sees few stars there the limits of the system must be near to him, where many, there the system has a great extension Now applying this plan, Sir Wm Herschel was led to the conclusion that the sidereal system is of the figure of a cloven disc, the sun being nearly at the centre, but somewhat nearer to its northern than its southern surface, and not far from the line in which the two laminæ of the cloven part of the disc intersect Sir John Herschel, applying a similar series of researches to the southern heavens, was led to a conclusion not absolutely identical with that reached by his father He was led to believe that the stars down to about the 10th or 11th magnitude, that is, all the stars within a sphere far more extensive than that which includes the lucid orbs, are spread more sparsely throughout space than those which form the galactic circle Instead therefore of a cloven disc, the sidereal system came to be regarded by Sir John Herschel, at least as regards its richer portions, as a cloven flat ring

According to both theories, however, it follows that the milky light of the galaxy comes from orbs situated at distances enormously exceeding those which separate us from the faintest stars visible to the naked eye Neither theory, therefore, affords any explanation of the fact, which is placed beyond all question, that the stars visible to the naked eye affect the regions covered by the Milky Way It is obvious that the distant stars of either theory could not in any case, save by the merest accident, seem specially associated with the stars visible to the naked eye, which lie at less than one-eightieth part of their distance from us, and accident is not a reasonable interpretation of repeated coincidences of this sort

We seem forced then to conclude that the hypothesis on which the researches of both the Herschels were based is a mistaken one As Sir William Herschel was led to suspect towards the close of his career as an observer, a real richness of stellar aggregation may be the true interpretation of the richer gauges, instead of an enormous extension of the system in the direction along which those gauges are obtained, or, rather, we are forced to recognise the former as in many cases the true interpretation

Unfortunately it is a legitimate deduction from this that the gauges made at the expense of so much labour by these two eminent astronomers, are practically valueless, at least in so far as the purpose for which they were made is concerned If we have no reason to believe that a general uniformity of stellar distribution prevails, we can place no reliance whatever on the Herschelian plan of star-gauging In counting stars the Herschels were in fact not counting suns as they supposed, but *points of light*

It may be questioned, indeed, whether a clearer insight may not be gained into the real nature of the Milky Way by the consideration of its more obvious features If we contemplate this wonderful zone as seen on the heavens when the sky is clear, we may be led to recognise peculiarities of structure which are markedly opposed to the theory of Sir William Herschel This is specially the case as respects the brighter parts of the galaxy in Cygnus and Aquila It seems impossible to consider this part of the heavens attentively without being led to the conclusion that we are regarding a stream of small stars, with which the lucid stars are most intimately associated But it is in the southern skies rather than in our poorer heavens that the real character of the Milky Way is most distinctly shown. The whole of the Milky Way between Argo and Scorpio, as described and figured by Sir John Herschel, forces on us the conclusion that neither the cloven disc theory nor the cloven ring theory adequately represents the complexity of the galaxy Whether we consider the fan-shaped expansions in Argo and the wide dark rift which separates them, or the well-defined boundary of the Milky Way near Crux, or the Coal-sack within that constellation, or the complicated structure of the galaxy over Scorpio, it seems impossible to accept any other interpretation than that the Milky Way consists of really small stars, in clustering aggregations of different figure which have been swayed by the attractions of the larger orbs into their present position

For further information on the subject of the Galaxy regarded in its relation to the sidereal system, &c, see *Sidereal System*, *Star*, *&c*

GALENA Native sulphide of lead, containing 86 57 per cent. of lead and 13 43 per cent of sulphur It is the principal ore of lead

GALILEAN TELESCOPE The form of telescope which was invented by Galileo It consists of an object glass and a concave eye-glass placed within the focus, this construction is now seldom used for anything but *opera glasses*

GALL See *Bile*

GALLIC ACID An organic acid contained in most astringent parts of plants It crystallises in long silky needles, slightly soluble in cold water, but very soluble in alcohol Formula $C_7H_6O_5$ When heated to 215° C (419° F) it decomposes into pyrogallic and carbonic acids It is a weak acid, and forms salts with bases. The *Gallate* of *iron* is the principal constituent of black ink.

GALVANIC BATTERY See *Battery, Galvanic*

GALVANIC CIRCLE A single galvanic cell together with the interpolar wire, or wire which joins the two metal plates, is sometimes called a *galvanic circle*.

GALVANIC CIRCUIT See *Circuit, Galvanic*

GALVANIC CURRENT See *Current, Galvanic*

GALVANIC PAIR A single cell of a battery (see *Battery, Galvanic*,) containing the *pair* of metals, such as zinc and copper, and the exciting liquid, such as sulphuric acid, is frequently spoken of as a *Galvanic Pair*

GALVANIC PILE See *Pile, Galvanic*

GALVANIC SPARK. See *Spark, Galvanic.*

GALVANISM That part of electric science, which is concerned with current electricity, is often treated of under the name *Galvanism*, (from Galvani, professor of anatomy at Bologna, 1790, the first investigator in this field) Galvani was engaged in examining the supposed connection between electricity and animal life, when he was struck by an observation of his wife that the limbs of some frogs, which had been skinned for eating, and, by chance, placed near to an electric machine, contracted every time a spark passed from the machine Galvani determined to pursue the matter further, and was soon led to the discovery that the thighs of a frog, skinned and suspended, would serve for a very delicate electroscope, on the same principle as the double gold-leaf electroscope (*q v*) It was while employing them for this purpose that he chanced upon a further discovery He had suspended some pairs of limbs upon an iron rail, and was employed in testing for atmospheric electricity with their aid, when he noticed contraction taking place, which he could not account for by its presence On looking further he found that these contractions occurred when the lumbar nerves were connected metallically with the crural muscles Galvani immediately attributed the contraction to electricity, and believed that the electricity, which he supposed to be the *vital fluid*, passed from the nerves to the muscles by means of the metallic connection, and by its discharge into them caused the motion.

The discovery of Galvani soon produced a host of inquirers, and the hypothesis which he put forward to account for it a host of opponents and of supporters The physiologists, as a rule, accepted his theory, and the most celebrated of those who denied it was Volta, professor of physics at Pavia He, noticing that the contraction in the limbs of the frog were more violent when the metallic connection between the muscles and nerves is composed of two

metals joined together, attributed the production of electricity to the metals, and showed that the presence of the limbs of the frog is unnecessary, in a way that will be explained immediately A memorable contest thereupon arose, and Galvani finally proved the existence of animal electricity (see *Electricity, Animal*), though obliged to admit that, at least, part of the phenomena he had noticed are not dependent on it

The following is what is commonly known as *Volta's Fundamental Experiment* — Having prepared a bar composed of a rod of zinc, and a rod of copper joined end to end, he held one end of the bar in his hand, and applied the other to one of the plates of his newly invented *condensing* electroscope (see *Electroscope* and *Condenser*), while he placed the other hand on the other plate He then removed his hand from the electroscope plate, afterwards withdrew the metal rod from the other plate, and finally raised the top plate of the electroscope from the other On doing so, he found the electroscope charged, and he accounted for the phenomenon by supposing that, at the junction of the two metals, there is a disturbance of electric equilibrium whereby the copper and zinc become oppositely electrified He looked upon the junction of the pair of metals as the place where the electric excitement takes its rise, and considered the limbs of the frog in Galvani's experiment merely as a conductor through which a flow of electricity takes place

With this theory to guide him, Volta constructed his pile in the year 1800 Considering that a single pair of metals produce but little effect, he saw that, by placing a series of pairs with a conductor between each pair, he would obtain a discharge of increased power He therefore constructed a *pile* consisting of pairs of zinc and silver placed in a constant order, inserting between each pair a piece of cardboard wet with water, and he obtained by means of it powerful effects in his electroscope, and on application to frogs' limbs, and with about forty pairs received a shock in the hands and arms The power of the pile remained as long as the cardboard was sufficiently wet The pile was described in two letters to Sir Joseph Banks, which are in the Philosophical Transactions for 1800

Very shortly after, Nicholson and Carlisle in England applied an instrument, known as Nicholson's Revolving Doubler (an electric machine founded upon statical induction, and fitted for delicate electric testing), to the pile, and showed that the silver end is negatively, and the zinc end positively electrified *

While experimenting with the pile, these naturalists had immersed the ends of wires coming from the extremities of it in water, intending to make the water a portion of the conducting circuit, when they were struck by seeing small bubbles of gas given off from one of them This led to the discovery of electrolytic decomposition (see *Electrolysis*), and six years after (1807) in the hands of Sir Humphry Davy, to the decomposition of potash and other oxides, till then supposed to be elements, and to the isolation of the metals which correspond to those oxides

Nicholson and Carlisle also observed chemical decomposition going on within the pile, and Davy put forward a theory which attributes the electric excitement to chemical action This was the origin of the celebrated *Chemical Theory*, which is opposed to Volta's *Contact Theory*, and which had for its supporters Wollaston, Parrot, De la Rive, Faraday There is still division as to the merits of the two theories, but the greatest authorities are in favour of Volta's Contact Theory, modified, or rather supplemented, in accordance with our present knowledge of facts, and with the known laws of the correlation of forces

The fundamental principle of the chemical theory is that in the chemical action of a liquid upon a metal, the metal is charged with negative, and the liquid with positive, electricity In the case, then, of the pile which consists of a series of zinc, moistened paper, and silver discs arranged as represented—

$$- Z f S \; Z f S \; Z f S, +$$

where Z, f, and S represent zinc, fluid, and silver respectively, the first Z becomes negatively electrified, and the first f positively, at the surface of contact between them, the fluid by electrolytic discharge (for a theory of electrolytic discharge, see *Grotthuss' Hypothesis*) communicates this charge to the silver, and the silver by conduction communicates it to the next zinc, at the second surface of contact between the zinc and fluid a still higher state of electric excitement is produced, and so on, till finally, between the last silver and the first zinc, a high difference in electric state exists, and, on connecting them together by means of a wire discharge, takes place through it. But no sooner has that occurred than a fresh charging by means

* This statement is apparently at variance with the ordinary phraseology which calls the silver end of the pile positive, and the zinc end negative The explanation will be found below, where it is shown that two of the plates, an external zinc, and an external silver plate, are now unused, being of no importance to the arrangement.

of new chemical action commences, and if the wire be again applied, a new discharge through it is obtained, or, lastly, if the ends of the pile be kept continually connected by the wire, continuous action goes on, which is called a flow of electricity The chemical theory is very fully stated and argued for in the treatise on electricity, by M De la Rive, vol ii, chap 3

According to the contact theory of the pile the seat of action is at the surface of contact of the two metals Volta showed, and though it has been denied, and though attempts to explain it away are made by the supporters of the chemical theory, it is completely established, that on bringing together two different metals there is electrical disturbance, one of them becoming positively, and the other negatively, electrified Thus we have seen that in Volta's fundamental experiment the condensing electroscope was charged by means of a compound bar of zinc and copper The zinc, in fact, becomes positively, and the copper negatively, electrified Volta considered that the office of the liquid is to conduct the electricity, and constructed his pile as represented below—

S Z *f* S Z *f* S Z *f* S Z

Between the first silver and the first zinc a difference of electric state is produced by the tendency of the zinc to become positive with regard to the silver, the fluid, being a conductor, raises the second silver to the same state as the first zinc, at the next surface a further disturbance takes place, and the second zinc becomes still more highly excited in comparison with the first silver, than was the first zinc, the same occurs throughout the whole of the series, and the last zinc is put in a high state of electric excitement with respect to the first silver, and on connecting with a wire discharge takes place But the office of the liquid is not simply that of a conductor, the discharge through it takes place electrolytically, chemical action going on at the zinc surface, and it is owing to this chemical action, that a current is kept up, the occurrence of which would otherwise be at variance with the laws of correlation of forces In order to complete what has been said with regard to the construction of Volta's pile, it is to be remarked that the extreme plates of zinc and silver represented above are unnecessary, for it will be noticed that, on connecting them by a wire, the tendency of the last zinc and first silver is opposite in direction to that of all the other pairs, and hence, though there is one more pair by number, there is no additional effect The pile complete then stands thus —

Z *f* S Z *f* S Z *f* S

Experiments on the contact electricity of metals were made by Sir W Thomson and Dr Joule, and are described in the Proceedings of the Literary and Philosophical Society in Manchester, and a more recent paper on the same subject is published in the Proceedings of the Royal Society for 1860

According to the plan of this work the various subjects connected with galvanism are treated of under the various names which refer to them Thus the articles on *Current, Electric*, *Battery, Galvanic*, *Electro-Dynamics*, *Magneto Electricity*, &c, *Electrotype*, *Telegraph, Electric*, and so on, may be consulted for information on these points

GALVANIZED IRON See *Zinc*

GALVANOMETER (*μέτρον*, a measure) An instrument for detecting the existence of, and determining the direction and the strength of an electric current In all galvanometers the principle of the action is the same It depends upon the force which Œrsted discovered to be exerted between a magnetic needle and a wire carrying a current, a force which tends to set the needle at right angles to the direction of the current, and whose intensity, other things remaining the same, depends directly upon the strength of the current (See *Electro-dynamics*)

There are several forms of galvanometer, of these the *astatic* galvanometer is described under its more common name of *Multiplier* Here we shall give an account of the *Tangent Galvanometer*, the *Reflecting Galvanometer*, and the *Marine Galvanometer*

(*a*) *The Tangent Galvanometer* In this instrument a very short needle is delicately supported so as to move in a horizontal plane over a circle divided into degrees The point upon which the needle turns is placed at the centre of a vertical circle of very thick copper wire through which the current passes, entering and leaving it by two binding screws The length of the needle is not more than a tenth of the diameter of the copper circle, and for convenience of observation very light pointers are frequently attached to its ends In order to use the instrument it is placed with the plane of the vertical circle parallel to the line in which the needle points, that is, to the magnetic meridian, and the current is sent through the circuit The needle is deviated to one side or other, and from noting to which side the north end goes the *direction* of the current is determined according to Ampère's rule, (*q v*), the angle of deviation is also noted, and from this the *strength* of the current is inferred. For it admits of

proof that in the instrument we have described, if the length of the needle be small compared with the diameter of the circle in which the current passes, then the strength of the current is proportional to the *tangent* of the angle through which the needle turns Hence the name *Tangent Galvanometer*

(β) In the *Reflecting Galvanometer* of Sir William Thomson a very small, light needle, made of a short piece of fine watch-spring, is suspended by a single silk fibre at the centre of a coil of insulated copper wire To the needle a very light mirror two or three tenths of an inch in diameter is cemented, the needle, mirror, and cement, together weighing but a few grains The mirror is concave and concentrates a beam of light to a focus about 40 inches (1 metre) distant At this distance is placed a horizontal scale with a slit at the centre and a lamp behind it, and the image of the slit reflected back by the mirror falls upon the scale and indicates in this way the position of the needle Either by means of the action of terrestial magnetism, or with the assistance of fixed magnets, the length of the needle in its natural position is parallel to the plane of the coils of the wire, and from what has been said it will be understood that a current passing through the wire deflects it, the angle through which it turns depending upon the strength of the current It is easy to show that the angle read off on the scale is double of that through which the needle turns

(γ) *The Marine Galvanometer* is also an invention of Sir W Thomson It is, in fact, a reflecting galvanometer peculiarly adapted to use at sea, an instrument being required in the laying of submarine cables which should be at the same time of the utmost delicacy for testing purposes, and should not be affected by the movements of the ship The general construction of the marine galvanometer is much the same as that of the instrument we have just described The mode of suspension of the needle differs in that the needle and mirror are attached to a vertical silk fibre stretched between two points, the line of suspension passing as accurately as possible through the centre of gravity The mirror and needle weighing only a few grains, the rolling of the ship does not alter their position so far as the instrument is concerned In order to avoid the influence of the magnetism of the earth and of the ship the whole instrument is enclosed in a case of wrought iron having only a window in front for the light to pass through to the mirror The adjustment of the mirror to zero is accomplished by means of magnetic bars placed inside the case, and the position of them can be altered by means of screws so as to make the instrument more or less sensitive as required

Besides the instruments which we have described there are a few others which are more rarely employed Thus there is the *Sine Galvanometer*, whose construction is much like that of the tangent galvanometer, but the method of using which is somewhat different The name is derived from the fact that the strength of the current is proportional to the *sine* of the angle observed

There are also *indicators* which, without measuring a current, show that there is or that there is not a current passing through them, and there are *differential* galvanometers in which two currents act upon the needle at once, tending to turn it in opposite directions, and their strength are compared by means of the instrument, but for description of these we must refer the reader to the various detailed works upon the subject of electricity

GAMUT, or *Musical Scale* If two notes are sounded together the ear is gratified when the number of vibrations per second of the one note stands in some simple arithmetical relation to that of the other Hence if we start with a note which consists of say 132 vibrations per second (C), and examine the notes whose vibrations stand in the simplest relations to this, we find a series of numbers, 16½, 33, 66, 132, 264, 528, &c, each of which is the double of the preceding number and half of the succeeding one Each note, therefore, is an octave above one and below the other of its neighbours, and any two will form a harmonious combination when sounded simultaneously In general terms, if m be the number of vibrations of a given note, the number of vibrations of a note n octaves above it will be $m\,2^n$, and that of a note n octaves below will be $\frac{m}{2^n}$. In musical instruments whose notes are limited in number and definite, the interval between one of these fundamental notes and its neighbouring octave is divided into twelve intervals The method employed is either that of "equal temperament" or that of as far as is possible harmonic division In the first system, every note must have $\sqrt[12]{2}$ or 1 05964 times as many vibrations as the lower neighbouring note In the harmonic division of the octave interval certain leading notes are fixed in the interval, whose pitch bears the simplest possible relation to the two extremes, as 5/6, 4/5, 3/4, 2/3, and the remaining notes are interpolated in such a manner that the secondary notes may have as nearly as possible a similar simple relation to one another These subdivisions are not always the same. The method of division by equal temperament promises to supersede the others.

GARLIC, OIL OF. See *Allyl Alcohol.*

GAS BATTERY In this form of battery, constructed by Grove, advantage is taken of the current produced when two plates of platinum, which have been used as electrodes in a cell for decomposing water, are connected together Let two such plates, one of which has formed the negative electrode, or that at which hydrogen is given off, and the other the positive electrode at which oxygen is liberated, be placed in water acidulated with sulphuric acid, and let them be connected with the terminals of a galvanometer, it will be found that a current proceeds from the hydrogen plate through the liquid to the oxygen plate The explanation of this phenomenon is that hydrogen and oxygen are deposited on the platinum plates in an active condition during the decomposition of water (See *Plates, Polarization of*) The hydrogen has a great tendency to combine with oxygen, and the oxygen a great tendency to combine with hydrogen This gives rise to chemical action and a current between the plates The gas battery constructed to utilise this current consists of cells which are constructed in the following way Two long glass tubes, closed at one end, each having a platinum ribbon extending along its whole length, and supported by a platinum wire passing through the closed end of the glass, are filled and inverted in a suitable vessel containing sulphuric acid and water, and by means of the wires passing through the glass a battery is applied, and the tubes are filled, one with oxygen, the other with hydrogen (See *Electrolysis*) The battery is then cast off, and if the wires from the tubes containing the gases be connected with the galvanometer, a current is observed to take place as has been described At the same time the gas in the tubes is seen to be consumed, and it is gradually turned into water again, the current flowing till all the gas has been used up The gas battery is made by connecting several of their cells together, oxygen to hydrogen, and then passing the current through them all at once from a sufficient battery With eight or ten cells sparks may be obtained, and the ordinary phenomena of chemical decomposition may be exhibited

GASES, ABSORPTION OF, BY SOLIDS AND LIQUIDS (*Absorbeo*, to suck up) Absorption, which plays so important a part in the arrangement of nature, appears to be a sort of penetration of the molecules, or rather of minute portions, of one kind of matter within pores or interstices of another When a porous body such as charcoal is placed under favourable circumstances in a vessel containing a gas or vapour, it has the power of condensing within its pores an enormous volume of the gas or vapour, frequently of diminishing the bulk of the gas which it takes up, to an extent greater than that which would turn the gas into a liquid, and this absorption is not a chemical action, though the amount of it depends on the nature of the solid or liquid, and on the nature of the gas, for the chemical properties of neither is changed, and the gas may be wholly or almost wholly recovered with the aid of an air-pump

Charcoal is a body which has a very great absorptive power De Saussure in 1812 made a series of experiments with that body, and his results have been confirmed and extended by Dr R A Smith and Mr Hunter Mr Hunter has made a large number of experiments on the subject which are published in the *Philosophical Magazine*, 1863 and 1865, and in the *Journal of the Chemical Society* for 1865, 1867, and 1868 The latter are concerned with the absorption of the vapours of bodies, liquid or solid, at ordinary temperatures. In the following table by Saussure, taken from Miller's *Elements of Chemistry*, the volumes of different gases absorbed by freshly burned boxwood charcoal are given, the volume of the charcoal being taken as 1 The experiment is made by introducing charcoal red-hot under the surface of mercury, and, without exposing it to the air, passing it into a vessel inverted over the mercury and containing the gas. The diminution of volume is thus noted —

ABSORPTION OF GASES BY CHARCOAL.

	Volumes.		Volumes
Ammonia,	90	Olefiant Gas,	35
Hydrochloric Acid,	85	Carbonic Oxide,	9 4
Sulphurous Acid Gas,	65	Oxygen,	9 2
Sulphuretted Hydrogen,	55	Nitrogen,	7 5
Nitrous Oxide,	40	Marsh Gas,	5 0
Carbonic Acid Gas,	35	Hydrogen,	1 7

Different kinds of charcoal have different powers of absorption Thus Hunter showed that while boxwood charcoal absorbs 85 6 volumes of ammonia gas, logwood charcoal absorbs 111 3 vols, ebony charcoal, 106 7 vols, and charcoal made from the shell of the cocoa-nut, 171 7 vols.

But by far the most interesting case of absorption by solids is that of the absorption of gases by the metals For the investigation and explanation of what we now know on the subject, we are indebted to the late Master of the Mint, Professor Graham. The powers which spongy platinum has of condensing gases at its surface has long been known A jet of hydrogen allowed to fall upon a small mass of spongy platinum, by its condensation raises the platinum

to an intense heat, and, if there be oxygen present, becomes ignited This fact is made use of in the Doberemer's lamp Or if a slip of platinum foil be held in the flame of a Bunsen's burner till it is thoroughly cleaned, and if the flame be then extinguished and the foil be allowed to hang within the tube, while the gas mixed with air rises around it, it will be found to glow for any length of time for a similar reason But Deville and Troost showed that hydrogen is absorbed into iron and platinum when hot, and Graham, in May 1867, showed that meteoric iron contains hydrogen, having been probably, if not certainly, cooled in an atmosphere of that gas Graham showed also that hydrogen gas passes through heated platinum He found that through a plate of platinum, in size one square metre and 1 1 millimetre thick, 489 2 cubic centimetres of the gas passed in one minute. He considered that the gas was absorbed as a liquid and then given out on the other side On examining the power of absorption for hydrogen of platinum in different forms he found wrought platinum, when heated and allowed to cool in the gas, to take up 5 53 volumes, hammered platinum, 2 28 to 3 79 vols, fused platinum, 0 171 of its own volume Oxygen and the other gases are scarcely, if at all, absorbable by the metal In the case of palladium, however, he was led to a most unexpected result In a paper of May 1868 he showed that palladium, when made the negative electrode of a galvanic battery, so that hydrogen is set free upon its surface, takes up 935 volumes of the gas, or 0 723 parts by weight, that the properties of palladium are much altered by the absorption of hydrogen, and concluded that hydrogen thus condensed becomes a metal which he names *hydrogenium*, and whose specific gravity he calculated as 1 708 Graham was led by these and similar experiments to the division of metals into crystalloid and colloid, and believed that the passage of hydrogen into palladium is analogous to the diffusion of a liquid through a colloid body We must refer the reader for details on this most interesting subject to his papers published in the Proceedings of the Royal Society, which we have mentioned above, and to two read in January and June 1869

On the subject of the absorption of gases by liquids the researches of Bunsen are by far the most complete Bunsen examines the laws of absorption of a gas by a liquid when the bodies do not act chemically upon each other He determined the value of what is called the *coefficient of absorption* for various gases, that is, the quantity of the gas which is absorbed by the unit volume of a given liquid at standard temperature (0° C, 32° F), and pressure (760^{mm}, 29 92^{in}), and established the laws according to which the amount of absorption is altered by a change in temperature and pressure The following table from Miller's *Elements of Chemistry* gives the coefficients of absorption for various gases in water and alcohol The results are those of Bunsen and Carius —

Gases	Volumes of Gas Absorbed by one Volume of Water	Alcohol
Ammonia,	1049 60	
Hydrochloric Acid Gas,	505 9	
Sulphurous Acid Gas,	68 861	328 62
Sulphuretted Hydrogen,	4 3706	17 891
Carbonic Acid Gas,	1 7967	4 3295
Nitrous Oxide,	1 3052	4 1780
Olefiant Gas,	0 2563	3 5950
Nitric Oxide,		0 31606
Marsh Gas,	0 05449	0 52259
Carbonic Oxide,	0 03287	0 20443
Oxygen,	0 04114	0 28397
Nitrogen,	0 02035	0 12634
Air,	0 02471	
Hydrogen,	0 01930	0 06925

Bunsen showed that if the temperature is constant the weight of the gas absorbed varies directly with the pressure, a law which was given first by Dr. Henry, and that the quantity of the gas absorbed diminishes with the pressure, and he gave a formula, with constants obtained by observation, for calculating the quantity absorbed at any temperature, the pressure remaining constant We must refer the readers to Bunsen's original papers in Liebig's *Annalen*, and in the *Philosophical Magazine*, 1855, and to *Gasometric Methods*, by R Bunsen, translated by Roscoe, for details and numbers

When a mixture of gases is in contact with a liquid the amount absorbed of each is proportional to its volume in the mixture multiplied by its coefficient of absorption, corrected, of course, for temperature and pressure. Thus, in the case of common air, dissolved in water, the proportion of oxygen to that of nitrogen, at 60° F., is 40 to 66, while the constituents of air

are mixed in the proportion of 1 to 5, roughly speaking This observation will be found to agree with the rule just given

In nature the absorption of gases by liquids is of the highest importance It is by the air absorbed in water that submarine plants and animals are sustained The life of trees depends upon the absorption of carbonic acid from the air, and in the lungs of the higher animals it is by absorption that oxygen is communicated to the blood

GAS, DIMINUTION OF LIGHT OF, BY ADMIXTURE OF AIR See *Diminution of Light of Gas by Admixture of Air.*

GAS ENGINE This name is given to a class of engines of small power which are worked by the ignition of coal gas mixed with air There are several varieties in common use, the main features however are the same in all The construction of a gas engine is usually the same as a horizontal steam engine in all respects, excepting in the parts for conveying alternately to the right and left of the piston gas instead of steam The gas is not usually led from the main directly into the cylinder, but is admitted in measured quantities into a kind of vessel from which it passes first into a small mixing chamber, where it is mixed with the required quantity of air, and then into the cylinder, its admission being governed by a slide valve In some engines, of which the *Lenoir gas-engine* may be taken as the type, the gas is ignited by an electric spark which is caused to pass at the proper instant within the cylinder In the *Hugon engine* the ignition is effected by two small gas jets carried in the recesses of the slide valve, one for each end of the cylinders These jets are supplied with gas by short flexible tubes which accommodate themselves to the movement of the valve Each jet, as it in turn effects the ignition of the explosive mixture, is extinguished, but at each stroke the recesses containing the gas-jets are brought outside the respective ends of the faces between which the valve works where the moveable jets are relit by fixed jets which are kept permanently burning A spray of water is admitted into the cylinder at each stroke, and being converted by the heat of the cylinder into steam adds to the power of the engine, and acts as a lubricator.

GASES, ELASTICITY OF See *Elasticity of Gases*

GASES, INDEX OF REFRACTION OF Gases refract light which enters them from a medium of different density, as in the case of solids and liquids (See *Table of Refractive Indices of Gases, Refraction, Index of*)

GASES OF BLAST FURNACES See *Iron*

GASES, RESISTANCE OF, TO MOVING BODIES See *Resistance of Gases to Moving Bodies*

GASES, SIDE PRESSURE OF MOVING See *Side Pressure of Moving Gases*

GASES, SPECTRA OF INCANDESCENT See *Geissler's Tubes*

GASES, WEIGHT OF See *Weight of Gases*

GASOMETER is the name usually given to the apparatus employed in laboratories for collecting, storing, and approximately measuring considerable quantities of gases It is also used for the large reservoir employed for collecting and distributing coal gas used for illuminating purposes The gasometer of the laboratory consists essentially of an iron cylindrical vessel closed at top and bottom, above which is supported a cylindrical trough A hole near the bottom of the cylinder can be closed by a screw (*a*) Near the top of the cylinder is a cock (*b*) communicating with the outer air Two tubes communicate between the cylinder and the trough, the one (*c*) reaches down to the bottom of the cylinder, the other (*d*) passes only just through its upper end, both are provided with cocks Finally, a glass tube running parallel to the cylinder and close to its side communicates with the top and bottom of it This serves as a gauge for seeing how full the gasometer is of gas If the gasometer be filled with water, and all the cocks be shut, the screw plug (*a*) may be opened without the water coming out on account of the atmospheric pressure The end of a gas delivery tube may be inserted into this hole and the gas collected, water of course flows out at the hole When the vessel is full the plug may be inserted and the upper trough filled with water On opening the cock (*c*) the air in the gasometer will be put under pressure, and it may be collected or used as it issues by opening the cocks, (*b*, or *d*)

GASSIOT'S TUBES See *Vacuum Tubes*

GAUSS' MAGNETOMETER See *Balance, Bifilar*

GEISSLER'S TUBES (So named from the manufacturer) When gases are highly rarified they conduct electricity of high tension, and the minute residue of each particular gas remaining in a so-called vacuum gives very characteristic colours, and spectrum phenomena A Geissler's tube consists of a hard glass tube containing what is technically known as an oxygen vacuum, a nitrogen vacuum, a hydrogen vacuum, a carbonic acid vacuum, &c, and furnished at each end with a platinum wire passing through the glass The inner extremities of the platinum are generally connected with aluminium wire If a Geissler's tube is contracted in any portion the luminous appearance is greatly intensified, and if glass of different composition

is employed for different portions of the tube (Uranium glass for instance), the phenomena of fluorescence and consequent change of tint are very striking For exhibition these tubes are made of an endless variety of forms and shapes and contain spirals, crosses, globes, vases, and other devices inside them The current is supplied from an induction coil, and when of appropriate strength, and the vacuum tube suitable, very beautiful stratifications are seen to cross the tube The light from a carbonic acid vacuum enclosed in a narrow spiral tube, is sufficiently powerful to be used as an illuminating agent, under special circumstances where other sources of light would be inapplicable, such as for illuminating cavities in the human body for surgical operations When the light from these tubes is examined in the spectroscope, it gives a spectrum peculiar to each gas Under certain conditions of temperature and pressure, the spectrum of some gases suddenly changes (See *Spectra of the First, Second, and Third Order*, see also *Spectroscope*, *Spectrum Analysis*, *Vacuum Tubes*)

GELATIN A pale yellow translucent substance, somewhat elastic and vitreous, obtained from bones, cartilage, and other animal substances Isinglass is a very pure kind of gelatin obtained from the sturgeon, while common glue is an impure kind obtained from refuse animal matter Gelatin is insoluble in cold water, but swells and increases very much in weight after soaking in it, forming a jelly This dissolves in hot water A very dilute solution of gelatin has the property of gelatinising when cold, but prolonged boiling destroys this power The composition of gelatin is not definitely ascertained

GEMINI (The Twins) A sign of the Zodiac The sun enters this sign on about the 21st of May, leaving it on about the 21st of June Also, a constellation, occupying the zodiacal region corresponding to the sign Cancer The principal stars of this constellation must have varied little in relative brilliancy since the time when their quality first suggested the name of the asterism, as they are at present nearly equal in lustre Pollux is slightly the brighter, however It is a coarse quadruple star Castor is one of the finest double stars in the heavens

GEOCENTRIC (γῆ, the earth, and κέντρον, centre) A term used in astronomy to express the position or motions of the various members of the solar system referred to the earth's centre The apparent motion of the moon, as seen from any place on the earth's surface, differs appreciably from the moon's calculated geocentric motion As regards the other members of the solar system, however, the geocentric motion is not considered by way of comparison with the apparent motion, but as distinguished from the *heliocentric motion*, (*q v*) The *geocentric longitude* of a planet is the angle included between two planes, both passing through the earth's centre and at right angles to the ecliptic plane, one passing through the planet's centre and the other through the first point of Aries It is measured from the first plane to the second, in the order of the signs The *geocentric latitude* of a planet is the angle which a line joining the centres of the earth and planet, makes with the plane of the ecliptic, and is reckoned north or south, according as the planet lies to the north or the south of the ecliptic

GEODESY (γῆ, the earth, and δαίω, to divide) In modern science, geodesy comprehends all those geometrical and trigonometrical processes by which the earth's surface is measured and surveyed It is on the comparison of such measurements with the results of astronomical observations indicating the relation between the points measured and the celestial sphere, that the determination of the earth's figure principally depends Thus geodesy will tell us that a certain line, measured from north to south, has a determinate length, but not what its figure may be, astronomy, by showing that the horizon plane at one end of the line differs in position from the horizon plane at the other, and also that this change of position of the horizon plane accrues uniformly along the line, shows that the line is the arc of a circle The description of the instruments used in geodesy belongs to mathematics, rather than to physical science, but many physical considerations have to be very carefully attended to in geodesy Amongst these we may note in particular—(1) Those which determine the laws of the expansion and contraction of metals under variations of temperature, (see *Expansion*), and (2) The effects of atmospheric refraction under different circumstances of pressure, temperature, and humidity

GEORGIUM SIDUS The name given by Sir Wm Herschel to the planet Uranus, which he discovered The name has long since become obsolete

GEOSTATIC ARCH See *Arch*

GEYSERS (Derived from an Icelandic word, signifying *roaring*) Hot springs in Iceland, which project masses of hot water, earth, &c, at intervals from their depths These springs follow the range of active volcanoes belonging to the Jokull or Icy Mountains Professor Tyndall thus describes the chief characteristics of the region where the Geysers are found "From the ridges and chasms which diverge from the mountains enormous masses of steam issue at intervals, hissing and roaring, and when the escape occurs at the mouth of a cavern,

the resonance of the cave often raises the sound to the loudness of thunder Lower down, in the more porous strata, we have smoking mud-pools, where a repulsive blue-black aluminous paste is boiled, rising at times in huge bubbles, which, on bursting, scatter their slimy spray to a height of 15 or 20 feet From the base of the hills upwards extend the glaciers, and above these are the snow-fields which crown the summits From the arches and fissures of the glaciers vast masses of water issue, falling at times in cascades over walls of ice, and spreading for miles over the country before they find definite outlet " It is beneath the morasses thus formed that the volcanic rocks lie, to whose heat the production of the Geysers is primarily due.

The explanation of the phenomena presented by Geysers is due to Professor Bunsen It may be thus presented —Beneath a geyser basin there is a tube filled, as is the basin in part, with water at a high temperature With the processes which have led to the formation of this tube we are not here concerned it is necessary to note, however, that the tube is communicated with by ducts from below, in which steam is generated from time to time by the heat of the subjacent rock But although the water in the tube is always hot, yet we must conceive of it as not heated at any time (not even just before an explosion) to the boiling point due to the pressure at each level throughout the tube The water is hottest at the bottom of the tube where the pressure is greatest, and therefore the boiling point highest From this point upwards the heat diminishes, but less rapidly below than higher up Hence at a certain height the heat approaches the boiling point nearer than at any height either above or below that point Now let us consider the result of this state of things It is probable that if nothing occurred to interfere with the heating process, the boiling point would be reached at some part of the tube, with results not differing remarkably from those which actually take place But Professor Bunsen has been able to determine the heat of the water a few minutes before explosion and he finds that at no part of the tube does the water actually reach the boiling point From time to time, as we have said, there is an inrush of steam through the ducts, followed by the rise of the water in the tube, the level of the water in the basin being obviously disturbed Now, suppose one of these inrushes to so raise the water in the tube that as the upper part of the raised water seeks its level in the basin, the pressure on the lower parts is diminished sufficiently to bring the boiling point of the water near the middle of the tube below the actual temperature The water is then immediately converted into steam at this point, the water above that point is further raised, and the pressure on the water below that point is further reduced, and is thus brought below the boiling point Hence all the water below the point where steam was first formed is suddenly converted into steam, the water above is hurled forth enveloped amid clouds of steam, and "we have the Geyser eruption in all its grandeur" After the eruption, the water, cooled by contact with the air, returns into the basin, and partially refills the tube It then gradually rises in the tube until the same state of things is restored as at first, to be followed by ebullitions, by "futile attempts at eruption," and at length, when the water in the tube is sufficiently heated, by a complete eruption as before

GIMBALS or GIMBALDS A name given to a pair of copper rings, within which the mariner's compass is slung, and which support it in such a way that the needle and card remain horizontal in spite of the pitching and rolling of the ship One of the rings turns upon a horizontal axis, resting on bearings attached to the compass box, the second, which is smaller, moves within the first, supported upon an axis at right angles to that of the first The compass bowl is placed within the smaller ring, and is so weighted that the pivot upon which the needle turns, and which is fastened to the bottom of the bowl, tends always to keep its vertical position (See *Compass, Mariner's*)

GLACIAL ACETIC ACID See *Acetic Acid*

GLACIER Immense masses of ice, formed by the compression of the snow which accumulates on the summits and slopes of mountains, and forces its way down into the valleys and ravines which furrow the mountain sides (See *Snow, Snow Line*)

The process by which glaciers are formed has given rise to some discussion Professor Forbes and others have attributed the phenomena presented during the gradual descent of the great ice masses, to a certain viscosity possessed by ice formed, as glacier ice undoubtedly is, by the compression of snow But Professor Tyndall has supplied abundant evidence in favour of the view that glacier ice possesses no viscosity whatever When subject to pressure, indeed, the ice behaves much as a viscous substance would, but when subjected to tension the ice shows at once that it is not viscous by parting asunder Thus,—Those deep gaps called crevasses are formed even when the descending ice has to change its angle of descent by so small a quantity as two or three degrees. Further, in a wide glacier, the general law according to which the central and upper portions of a glacier move faster than the sides, operates so as to produce but a very slight difference in the rates of motion of adjacent portions of the glacier. yet even this

slight difference (in one case so small, Professor Tyndall estimates, as $\frac{1}{80}$th of an inch in 24 hours) causes crevasses to form. Therefore Tyndall has put forward the theory (now generally accepted) that the peculiarities observed in the motion of glaciers are due to *regelation*, (*q v*) The ice of the glacier is brittle not viscous, and owing to its brittleness, it is crushed and broken in its descent but regelation causes the fragmentary masses to remain always bound together, since wherever they are brought into contact regelation immediately sets in

GLAISHER'S FACTORS A series of corrections of barometric, hygrometric, and thermometric indications, calculated by Mr Glaisher, and of great value to the meteorologist

GLASS The chemical composition of glass is that of mixed silicate of potassium or sodium with silicates of calcium, lead, aluminium, and others The mixture must be so proportioned that there is not sufficient alkaline silicate present to render the product attackable by water or acids Silicate of calcium increases the fusibility and also the resistance to the action of water Silicate of aluminium renders glass less fusible, and less liable to be acted on by water, whilst the more the potash, lime, or oxide of lead increase, the more fusible and soft the glass becomes Bottle glass has a specific gravity of 2 7, its composition is principally that of a mixed silicate of calcium and aluminium Ordinary window glass is approximately a mixed silicate of sodium and calcium. English crown glass contains silicates of potassium and calcium English crystal glass is a mixed silicate of potassium and lead Flint glass has a somewhat similar composition, but with varied proportions Faraday's heavy glass (specific gravity, 5 44) is a silico borate of lead Glass is coloured red by gold or copper, blue, by cobalt, yellow, by silver or iron, and green, by chromium (See *Silicates*)

GLAUBER'S SALT See *Sulphates, Sodium*

GLOBE, CELESTIAL A globe showing the constellations, and mounted as the terrestrial globe is The celestial globe serves to solve many elementary problems of astronomy The stars are not represented on a celestial globe as they actually appear on the heavens, but so that if they could be viewed from the inside of the globe, they would appear as on the sky

GLOBE, TERRESTRIAL A globe of wood or plaster covered with paper, on which are delineated the figures of the oceans, continents, &c, of this earth The globe, mounted so as to revolve on a polar axis under a brazen meridian, and inclinable at different angles to a wooden horizon circle, is often used to solve elementary problems of geographical astronomy.

GLOW DISCHARGE See *Discharge*

GLOWWORMS See *Fireflies, Examination of the Light from*

GLUCINUM, or, *Beryllium* (γλυκυς, sweet) A somewhat rare metal, the oxide of which was discovered by Vauquelin in 1798, in the beryl, whence the name beryllium Subsequently it was named glucinum, owing to the sweet taste of its salts Symbol, G or Be (the latter being usually adopted) Atomic weight, 4 7, if its oxide has the formula Be_2O_3, and 7 if its oxide is Be_2O; these points have not yet been satisfactorily determined Glucinum is a white metal malleable and ductile, possessing a specific gravity of 2 1 It melts below the melting point of silver, and does not oxidise readily in the air even when melted Acids attack it readily It forms an oxide which much resembles alumina, and unites with acids to form salts, which are colourless and in general easily crystallised The beryl is a silicate of glucinum.

GLUE See *Gelatin.*

GLYCERIN (γλυκυς, sweet) A syrupy colourless liquid, of a very sweet taste, and neutral to test paper Specific gravity, 1 26 It mixes with water and alcohol in all proportions Composition, $C_3H_8O_3$. It is contained in most fixed oils and fats, in which it exists in combination with fatty acids, and is liberated upon saponification It is non volatile at the ordinary temperature, but when heated in an atmosphere of steam it distils over Glycerin does not freeze or alter by exposure to the atmosphere, it has no poisonous or injurious properties, and on these accounts its uses in arts, manufactures, and for domestic purposes are very great When acted on by strong nitric acid it is converted into nitro glycerin (See *Nitro-glycerin*)

GOLD A metallic element of a beautiful yellow colour, soft, and extremely malleable and ductile Specific gravity, 19 258 to 19 367 It melts at 1200° C (2192° F), and volatilises slightly at a little higher temperature It does not tarnish in the air even when melted, and is unaffected by any single acid, but is dissolved by chlorine water and mixtures which evolve chlorine, such as nitro-hydrochloric acid Atomic weight, 196 Symbol, Au, from its Latin name *Aurum* It is found in almost all parts of the world, but seldom in large quantities, and almost invariably occurs native or alloyed with other metals It forms compounds with most of the other elements, but they are of comparatively slight importance They are readily reduced to the metallic state by heat The alloys of gold with silver and copper are of great importance, being used for coinage and jewellery. The only chemical compounds of gold which require mention are the *chloride of gold* ($AuCl_3$); this forms a dark red deliquescent mass,

which is left behind when a solution of gold in nitro hydrochloric acid is evaporated to dryness From an acid solution an acid chloride of gold and hydrogen crystallises in long yellow needles, which are very soluble in water Chloride of gold has a great tendency to form double salts with other chlorides, which are called chloroaurates The *Chloroaurate of Sodium* is employed in photography, it crystallises in long prisms, which are soluble in water but not deliquescent Its composition is $NaCl\ AuCl_3\ 2H_2O$ The chloroaurates of many organic bases are beautifully crystalline compounds, and are frequently prepared for purposes of analysis

GOLDEN NUMBER See *Cycle, Metonic*

GOLD MOSAIC See *Tin, Sulphide*

GOLD, RELATION OF, TO LIGHT The relation of gold to light was studied in an exhaustive manner by the late Professor Faraday (*Phil Trans* 1857, p 145) He conceived that it was possible that some experimental evidence of value might result from the introduction into a ray of light of separate particles having great power of action on light, the particles being at the same time very small as compared to the wave lengths He found that gold was especially fitted for these experiments on account of its comparative opacity, and yet possession of real transparency, because of its development of colour both in the reflected and transmitted ray, because of the state of tenuity and division which it permitted, with the preservation of its integrity as a metallic body, because of its supposed simplicity of character, &c Besides, the waves of light are so large compared to the dimensions of the particles of gold which in various conditions can be subjected to a ray, that it seemed probable the particles might come into effective relations to the much smaller vibrations of the ether particles The beaten gold employed averaged $\frac{1}{282000}$th of an inch thick, occupying in average thickness no more than from $\frac{1}{3}$th to $\frac{1}{4}$th part of a single wave of light, but by chemical means the leaf may be obtained so thin that 50 or even 100 may be included in a single progressive undulation of light, still remaining of a green colour by transmitted light If this thin film is annealed by exposure to the temperature of an oil bath for five or six hours, it becomes almost colourless, although microscopic examination shows that its continuity is unaltered When gold thus rendered colourless by annealing is subjected to pressure, it again becomes of a green colour When gold wire is deflagrated by explosions of a Leyden battery near a surface of glass, the particles are caught and are deposited as a film, golden by reflected light, and of a fine ruby colour by transmitted light, passing towards the edges to a violet colour, and sometimes appearing green When this deposit of divided gold, which is violet, blue, or green by transmitted light, is heated to dull redness, it changes to a ruby colour, still preserving its metallic yellow reflection, and when this ruby gold is submitted to pressure the transmitted ray changes from ruby to green By reducing gold from its solution by phosphorus a continuous film can be produced, so thin as to be invisible at first, then thickness perhaps not being $\frac{1}{500}$th of a wave undulation of light When a little thicker the film is a gray violet, which is changed by heat to purple, and afterwards to green when submitted to pressure Gold precipitated from a solution in the form of separate particles is of a ruby colour by transmitted light, but having the metallic lustre when exposed to sunshine These fine particles may be diffused through warm gelatine, and the jelly on cooling is of a rich ruby colour and can be dried to a film identical in appearance with ruby glass When common salt is added to a ruby gold fluid this is rendered blue The relation of polarised light to these gold films is of considerable interest On arranging the polariser and analyser so as to get a dark field, no effect was produced on interposing a piece of well annealed plate glass, this substance not having depolarising properties A piece of gold leaf attached to glass was then introduced between the analyser and polariser at right angles to the ray, when it was seen that the metal had depolarising powers, especially when it was inclined, the image of the analyser being brought out exceedingly well It is, indeed, very striking to see, when the plate is moved parallel to itself, the darkness when mere glass intervenes and the light which springs up when the gold leaf comes into its place, the opaque metal and the transparent glass having apparently changed characters with each other

GNOMON (γνώμων) This name was formerly applied to any rod whose shadow was intended to indicate any astronomical relation Thus the rod of a dial, which points to the pole of the heavens, is a gnomon (see *Dial*), and a vertical pillar, such as ancient astronomers used to determine the height of the sun at midday, was also called a gnomon The Egyptians, Chinese, Peruvians, and many other nations, made great use of gnomons of different sorts

GOMEISA (Arabic) The star β of the constellation Canis Minor

GONIOMETER. (γωνια, an angle, and μετρέω, to measure) An instrument for measuring the angles of crystals For this purpose Wollaston's reflecting goniometer is most frequently used It consists of a *divided circle* graduated to degrees, and subdivided with a vernier On the axis is an arrangement for supporting the crystal A distant object is viewed, reflected in one of the faces of the crystal, and the vernier is brought to zero The circle carrying the

crystal is then turned, until the same object is reflected from another face of the crystal, when the angle formed by the two faces can be read off on the circle Other adjustments and contrivances are introduced for the purpose of securing accuracy of reading When a microscope is fitted with a *position circle* and *micrometer*, angles of microscopic crystals can be measured with great accuracy

GOVERNOR A contrivance for regulating the supply of steam to the cylinder of a steam-engine, according to the speed It consists of two heavy balls attached to the extremities of two rods, the other extremities of the rods being jointed to a vertical shaft When the engine is in action, the shaft and the parts attached to it are made to revolve by a strap from the crank shaft of the engine, and consequently a centrifugal force is communicated to the balls which causes them to fly apart, so that the rods make angles with the central shaft which increase with the velocity of revolution Now the rods to which the balls are attached are connected by two other rods with a ring capable of sliding up or down on the vertical shaft, so that when the balls fly out the ring ascends, and when they fall it descends A long lever passes from the ring to a disc, termed the throttle valve, in the steam pipe from the boiler, and the connection is so arranged that, as the ring ascends, the valve closes Thus the engine itself regulates the supply of steam, for, as the speed increases, the supply is diminished, and when the maximum speed is attained, the steam is entirely cut off.

GORE'S ROLLING BALLS See *Trevelyan's Experiment*

GRAMME The French unit of weight See *Metric System.*

GRAPE SUGAR See *Sugar*

GRAPHIC REPRESENTATION OF FORCES (γραφω, to write, draw) Forces may be represented by straight lines, since the three qualities required to determine the effects of forces are also possessed by lines, thus the intensity or magnitude of a force is represented by the length of the line, the direction of the force by the direction of the line, and the point of action or application of the force by the extremity of the line Also, when a line is designated by two letters as A B, these are made to represent the directions of the force by always considering the force as acting in a direction from the first to the second, or from A to B, while the line B A would represent a force acting from B to A By means of this graphic method, the general principles of geometrical reasoning may be applied to deduce the mechanical effect produced by combinations of forces under given conditions

GRAPHIC REPRESENTATION OF VIBRATIONS A sound wave consists of a travelling state of compression It is clear that any quantity can be represented by any other quantity, and that therefore the quantity of density or compression may be represented by a straight line Hence, a region of variable compression may be represented by a series of straight lines of variable length If we imagine a series of waves to proceed from one point and reach another, and if we imagine a straight line to connect the two points, then the divers densities of the medium along that line may be faithfully represented by ordinates of different lengths set up upon the connecting line, and the curve connecting the extremities of the ordinates will be a faithful representation of the degrees of compression.

GRAPHITE See *Carbon*

GRAVITATION (*Gravis*, heavy) The name given to the great law, established by Sir Isaac Newton, that *every particle of matter within the universe attracts every other particle with a force proportional directly to the product of the numbers representing their mass, and inversely to the square of the distance separating one from the other* The term *gravitation* is commonly distinguished from the term *gravity* (*q v*), the former being applied to the operation of the great law throughout the interplanetary and interstellar spaces, the latter to the action of the earth's mass upon terrestrial bodies

The discovery of the great law of gravitation is intimately associated with the history of that great period of progress during which the Ptolemaic system was overthrown, and the Copernican established The discovery by Kepler of the three laws which bear his name, by indicating the existence of real laws harmonising the motions of the celestial bodies, invited research into the question how far these laws might depend on the action of some special form of force The nature of a central force under which a body would move in an elliptical orbit having a focus coincident with the centre of force, had been inquired into by Wren and Hooke, though the solution, even of this problem, which seems to modern mathematicians a simple one, was not given in a complete form until Newton had applied his powers to the work But the recognition of the general action of a central force exerted by the sun upon the bodies circling around him, and by the planets on their satellites, and the further recognition of the fact that bodies on the earth are drawn towards the earth's centre, though doubtless important, yet by no means suggested the existence of the great law Newton was to establish It is necessary, if we would rightly apprehend the grandeur of his work, to recognise what distinguished it

wholly from all that had been done or even suggested before his time. To suppose that Newton had only supplied mathematical proof of a law which had occurred to other minds would be largely to undervalue what science owes to him. It was the noble guess (for at first it was but a guess) that the forces, exerted by the earth upon terrestrial objects, by the planets on their satellites, by the sun upon the planets, are all manifestations of one form of attraction exerted alike by all forms of matter, and influencing all according to one uniform law,—it was this daring generalisation,—that distinguished Newton's work from all which had preceded it. Then, indeed, when this noblest of all laws had been suggested to his mind, there followed that wonderful series of labours by which he was enabled to give the hypothesis a firm foundation. In reading the history of those labours, one knows not whether most to admire the ingenuity of the mathematical devices employed by Newton, the clear sightedness of his reasoning, or the wonderful patience and caution with which he conducted the whole inquiry. All that he himself required to complete the proof of the law was satisfactory evidence, that the action which the earth exerts on terrestrial bodies corresponds with the influence she exerts upon the moon. To prove this it was necessary to show that a body at the moon's distance would, in a given short space of time, fall as far towards the earth under the influence of her attraction, as the moon is actually deflected in that time from the tangent to her orbit, through the place she had at the beginning of that time, such deflection being measured in a direction at right angles to that tangent. At first Newton's calculations failed to show this, the fact being that, according to the estimate of the earth's dimensions accepted in his time, the distance of the moon was greatly underrated. He accordingly, for nearly a score of years, gave up the theory of a universal law of gravitation as untenable. At length, in 1684, Picard's new measurement of the earth supplied Newton with the means of testing afresh his daring hypothesis. As the work proceeded, he found "the figures shaping themselves towards the desired end," and simple though the processes were by which the calculation was to be completed, he was so unnerved by his sense of the grandeur of the great law which was about to be established, that he had to commit the completion of the task to a friend. When the calculation was finished, the influence of the earth on the moon was found to be precisely the same as that which she exerts on objects near her, diminished only through the effect of distance, according to the law enunciated above.

But much more remained to be done in order that the law should be presented in a convincing manner before astronomers. Satisfied himself, Newton felt that, to satisfy the world, he must show the power of this great law of gravitation to interpret the most difficult problems of astronomy. He selected the lunar motions, and showed, by reasoning of amazing force and clearness, how all the chief lunar inequalities can be accounted for as due to the action of this omnipresent law. (See *Lunar Theory*.) The modes he employed were such, however, as none but he could have made available. It has been to the successful attempt, not only to account for celestial motions which Newton had left undealt with, but to detect by calculation peculiarities of motion which observation has not revealed, that modern analytical mathematics owes its origin and its rapid development.

The law of gravitation has been applied successfully to weigh the various members of the solar system, and even star against star, to explain the motion of the tidal wave and the paths of comets, and even to exhibit the origin of that wonderful vitality which pervades the solar system, and doubtless, in not inferior degree, the systems which circle around other suns.

GRAVITY. (*Gravitas*, from *gravis*, heavy, ponderous.) The term applied to the force with which the earth attracts every particle of matter. The effect of gravity is measured by the acceleration or the velocity generated in a body free to move under the action of the force. Although bodies of different material fall to the earth with different velocities when they encounter the resistance of the air, yet *in vacuo* all bodies fall through the same space in the same time, and acquire the same velocity. By experiments made at Leith Fort, Captain Kater found that the velocity acquired by a body falling unresisted for one second is at that place 32.207 feet per second. (See *Pendulum*.) The variation in this velocity for one degree of difference of latitude from that of Leith is only .0000832 of its own amount; the average value for the whole of Great Britain is very nearly 32.2 feet. The value of the velocity acquired in a second by a body falling freely decreases as we pass from the poles to the equator. Two causes contribute to this.

First, in consequence of the revolution of the earth, every point of it describes a circle in 24 hours; but the circumference described by a point nearer the equator is greater than that of one more remote; consequently the tendency of a body to fly off from the earth is greater at the equator than nearer the poles. But the force producing motion in a falling body is the force of gravity less this centrifugal force. Second, the earth is not a true sphere, but is flattened at the poles. Hence a point nearer the equator is further from the centre of mass

than a point nearer the poles, and consequently the force of gravity is less at the former than at the latter (See *Gravitation*) If a body be weighed by a spring balance at two places not of the same latitude, the weight at the higher latitude will be the greater The apparent force of gravity at any place is determined by ascertaining the length of a simple pendulum which beats seconds at that place The following table gives the lengths of the seconds pendulum at different places according to the Astronomer Royal, and the value of *g* which can be deduced from them —

THE VALUE OF THE ACCELERATING FORCE OF GRAVITY AT DIFFERENT PLACES

Observer	Place	Latitude	Length of seconds pendulum in inches	Accelerating force of gravity feet and seconds
Sabine, . .	Spitzbergen,	N 79°50′	39 21469	32 2528
Sabine, .	Hammerfest,	70 40	39 19175	32 2363
Svanberg,	Stockholm,	59 21	39 16541	32 2122
Bessel,	Konigsberg,	54 42	39 15072	32 2002
Sabine,	Greenwich,	51 29	39 13983	32 1912
Borda, Biot, and Sabine,	Paris,	48 50	39 12851	32 1819
Biot,	Bordeaux,	44 50	39 11296	32 1691
Sabine, . .	New York	40 43	39 10120	32 1594
Freycinet,	Sandwich Islands,	20 52	39 04690	32 1148
Sabine, .	Trinidad,	10 39	39 01888	32 0913
Freycinet,	Rawak,	S 0 2	39 01433	32 0880
Sabine and Duperrey,	Ascension,	7 55	39 02363	32 0956
Freycinet and Duperrey,	Isle of France,	20 10	39 04684	32 1151
Brisbane and Rumker,	Paramatta,	33 49	39 07452	32 1375
Freycinet and Duperrey, ,	Isles Malouines,	51 35	39 13781	32 1895

GREEN VITRIOL See *Sulphates, Iron*

GREGORIAN TELESCOPE This form of reflecting telescope was first proposed by James Gregory The rays of light falling on the principal speculum are reflected back to a small concave speculum placed beyond its focus, this returns them to the centre of the large speculum where a hole is cut to allow them to pass through to the eye piece The Newtonian Telescope is an improvement upon this

GREY CAST IRON See *Iron, Cast*

GRIMALDI'S FRINGES The fringes which are observed in the shadows of bodies formed by divergent light are sometimes called Grimaldi's fringes, after the first observer of them (See *Fringes, Diffraction*)

GROOVED SURFACES, COLOURS OF The iridescence of mother of pearl, micrometer scales, Barton's buttons (which see), &c, is due to the reflection of light from minute grooves on the surface giving rise to the production of colour by the interference of the waves of light (See *Interference of Light*)

GROVE'S GALVANIC BATTERY consists of platinum and zinc cells The zinc which is amalgamated, that is, coated with mercury, is immersed in an outer cell containing dilute sulphuric acid Within this is placed a porous cell which is filled with strong nitric acid, and in which the platinum plate stands On connecting together the platinum and zinc, the current [illegible] as follows The zinc decomposes the sulphuric acid and liberates hydrogen This, by a series of molecular reactions, gives rise to a second reaction in which the nascent hydrogen decomposes the nitric acid forming in the first place nitrous acid Afterwards further decomposition takes place, and dark red fumes of the oxide of nitrogen are given off By this decomposition of the nitric acid the polarisation of the platinum plate due to deposition of hydrogen is avoided The porous cell intervening between the sulphuric acid and the nitric acid does not hinder the chemical action from taking place, though it prevents the liquids from mingling

GROTTHUSS' HYPOTHESIS (from the name of the proposer) seeks to explain the phenomena of electrolysis According to it the molecules of bodies which undergo electrolysis are essentially composed of two atoms, or groups of atoms, one of which is electro-positive (see *Electro-positive*), and the other electro-negative. A chain of compound molecules thus made

up joins two points in the electrodes, and by the electric current the two extreme molecules are broken up, and a series of decompositions and recompositions takes place in the following way Towards the negative electrode goes the electro positive atom or group, while the electro negative atom or group of atoms goes to the positive electrode This action sets free at the respective sides an electro-negative and an electro-positive atom or group, and these throw all their attractive force upon the compound molecules next to them, decomposing them, and taking to themselves the complemental portions which they require in order to form complete compound molecules This second decomposition and recomposition gives rise to a third, and so on throughout the whole chain, the final effect, when a cycle of operations is finished, being that one whole molecule has been separated into its constituents, and a new chain has been formed, in which a fresh series of similar reactions can have way The theory certainly lends itself easily to the explanation of known facts

GRUS (The Crane) One of Bayer's southern constellations The stars forming this asterism present a somewhat remarkable figure, being so associated as to form a well marked stream

GULF STREAM, INFLUENCE OF, ON THE CLIMATE OF GREAT BRITAIN The name Gulf Stream has been given to the ocean current, which, passing from the equatorial parts of the Atlantic to the Gulf of Mexico, traverses the Atlantic eastwards, reaching to and beyond the shores of England Very unreasonable doubts have lately been cast upon the theory that the gulf stream exercises an important influence on the climate of Great Britain These doubts are principally founded on a total misapprehension of the way in which the neighbourhood of warm seas affect the climate of a country If the influence of the water in warming the air which is in contact with it were the only effect to be considered, the gulf stream could doubtless but slightly influence the climate of this country It is to the fact that from the gulf stream aqueous vapour is continually rising into the air that the great influence of this current upon our climate is to be attributed (See *Climate*) The moisture laden air not only brings to us the warmth of the gulf stream, distributed as the aqueous vapour becomes condensed, but also serves to prevent the radiation of heat from our plains, and hills, and valleys, into space

GUM A name given to several substances of different composition, but of similar properties exuding from stems and branches of trees, they are all more or less soluble in water, forming a thick glutinous liquid The principal gums are *Gum Arabic*, *Gum Senegal*, *Cherry Tree Gum*, *Bassora Gum*, *Gum Tragacanth*, and *Dextrin* or *British Gum* (See also *Dextrin*)

GUN COTTON, *Pyroxylin*, or, *Trinitro cellulose* A name applied to a nitro substitution compound of cellulose Cellulose has the composition $C_6H_{10}O_5$ Three of these equivalents of hydrogen are capable of being replaced by corresponding equivalents of nitric peroxide NO_2, forming a compound $C_6H_7(NO_2)_3O_5$, or trinitro cellulose This compound is insoluble in water, alcohol, or ether, and is unaffected by dilute acids or alkalies When exposed to heat it explodes with violence, and on this account is used as a substitute for gunpowder When exploded in the free state by heat it goes off with a sudden flash and is comparatively harmless, but when it is confined in a box, or when it is ignited by the powerful detonation of fulminating mercury its explosion takes place with terrific violence, and its effects much exceed those produced by corresponding amounts of gunpowder A variety of gun cotton containing less nitric peroxide than the trinitro compound is used in surgery and photography, as it has the property of dissolving in a mixture of alcohol and ether, and is left behind on evaporation of the solvents as a tough transparent skin

GUNNERY The art of charging, directing, and exploding all kinds of fire arms, though the term is commonly restricted to the larger pieces of ordnance To this art belongs the knowledge of the force and effect of gunpowder, and the methods of pointing and adjusting It is, therefore, partly theoretical and partly practical Theoretical gunnery consists in computing the angles of elevation, the velocity of projection and the range of the ball, from certain data previously known (See *Projectiles*) From experiments made at Woolwich by Dr Hutton, the following conclusions have been deduced —(1) The velocity increases with the increase of charge to a certain point, and then decreases as the charge increases (2) The velocity with equal charges increases with the length of the gun (3) The range increases in a much lower ratio than the velocity (4) No difference is caused in the velocity or range by increasing the weight of the gun (Hutton's Tracts, vol III, p 215)

The following rule, derived entirely from experiment, has been given, to find the velocity of any shot or shell, when the weight of the charge of powder and weight of the shot are known Divide three times the weight of the powder by the weight of the shot Extract the square root of the quotient and multiply the result by 1600, the product will be the velocity in feet

GUTTA PERCHA A substance much resembling India-rubber and obtained like it from the juice of certain trees, principally the *Isonanda Percha*, and the *Is Gutta* It is of a light

brown colour, of specific gravity 0 98 It is insoluble in water, and softens by heat, solidifying on cooling to a hard tenacious leathery mass Owing to its insulating properties for electricity it is largely used for coating telegraph wires The composition is not definitely made out, but it is a hydro carbon when pure It, however, appears to oxidise somewhat readily, and then becomes friable, losing its valuable properties

GYPSUM See *Sulphates, Calcium*

GYRATION, RADIUS OF (*Gyrare*, to revolve, γυρὸς, round) The distance from the axis of a rotating body, at which the whole mass of the body may be supposed to be collected, without producing any change in the moment of inertia It is a linear magnitude of great importance in the investigation of the properties of rotating solids, for example, when a solid body oscillates about a fixed axis, the time of oscillation is the same as that of a simple pendulum whose length is equal to the square of the radius of gyration with reference to the axis of suspension divided by the distance of the centre of gravity below the centre of suspension (See *Pendulum, Oscillations, Centre of*)

GYROSCOPE (γυρὸς and σκοπέω, to look) An instrument to illustrate the composition of rotations and the resistance which a rapidly revolving heavy body offers to a change of position in its axis of rotation It consists of a metallic disc, thin in the centre, but having a thick and heavy rim, capable of revolving upon an axis which forms the diameter of a brass ring This ring can be placed so that it turns about an axis forming the diameter of a second ring If the disc and first ring be detached from the second ring, and held in the hands while the disc is set rotating in any plane, it will be found that so long as no attempt is made to turn the disc, so that it shall revolve in another plane, the weight of the instrument only has to be supported, but a powerful resistance will be felt to an attempt to change the direction of the axis Again, if while the disc is revolving the ring be rolled along a level floor it will be found impossible to make it keep upright and to prevent it running out of the right line If the outer ring be suspended by a torsionless thread and rapid rotation be communicated to the disc which is then abandoned to itself, it will continue to rotate in the same plane until brought to rest by friction, since from the mode of suspension there is no force to cause the axis to take a new direction From this fact the instrument has been used by Foucault and others to demonstrate the fact of the earth's diurnal rotation If the disc be caused to rotate in a vertical plane so that its horizontal axis points to some object on the earth's surface, after a short time the axis will apparently have moved through an angle, the magnitude of which will depend on the latitude of the place Again, if the axis of the disc be made to point to a fixed star, then if the earth were at rest and the heavens revolved about it, as they appear to do, the star would move from the direction of the axis, but this is not the case, for the axis continues to point to the same star so long as the disc rotates, showing that the stars are fixed and the earth revolves

When the conditions of suspension are varied, the movements of the disc are always such as would result according to the theory of dynamics, from the composition of the rotation of the disc with that of the earth (See the Notices of Professor Powell in the *Transactions of the Astronomical Society*, April 1855)

H

HÆMATIN A crystalline substance, constituting the red colouring matter of blood It forms small indistinct crystals of a red brown colour, is tasteless and inodorous, insoluble in water, cold alcohol, and ether The formula is not well ascertained, but it is known to contain iron

HÆMATITE The minerological name of native sesquioxide of iron It is known also as native ferric oxide, red iron ore, oligistic iron, and sometimes as kidney ore In the pure state it contain 70 per cent of iron, the formula being Fe_2O_3 It occurs in the crystalline, massive, and earthy state in large veins or beds, and is one of the most valuable ores of iron

HÆMATOXYLIN The crystallised substance to which the colouring properties of logwood (*Hæmatoxylon Campechianum*) are due Formula $C_{16}H_{14}O_6$ It forms colourless transparent crystals, very brilliant and sometimes of considerable length It is slightly soluble in cold water, but more so in hot water, alcohol, and ether It has a strongly saccharine taste resembling that of liquorice Under the influence of alkalies and oxygen it rapidly changes to a colouring matter

HAIDINGER'S FRINGES OR TUFTS This term is applied to certain phenomena of light, first observed by Haidinger, by which a polarised beam can be detected by ordinary vision (See *Polarised Light*)

HAIL A shower of discrete pieces of ice (how formed, and under what laws is unknown), is called a hailstorm. Sir John Herschel considers that the fragments of ice in an ordinary hail-

storm are simply frozen rain drops. Where larger masses of ice are observed to fall, he considers *regelation* (*q v*) to have been concerned, and the great hailstones to have been formed during the "hurtling together of masses of ice in the air." Others attribute hail to the action of electricity in the upper regions of air. Undoubtedly hailstorms are always accompanied by electrical phenomena, but this fact does not in itself indicate an electrical origin, since a hail storm must necessarily be accompanied by a great commotion in the air, and the sudden commingling of saturated masses at different temperatures, so that electrical action would undoubtedly be excited. Therefore Sir John Herschel may be right in saying that, to attribute hailstorms to electricity, is putting the effect for the cause. But the evidence we have, scarcely justifies us in summarily rejecting all electrical hypotheses in accounting for hail storms, since no explanation has yet been given of the circumstances under which hailstorms appear, and of the phenomena they present. These are as follows —

Hail often falls before a heavy rain shower, very rarely following rain. The clouds from which hail falls are very dense, and somewhat resemble bronze in colour, they have irregular edges, and are at no very great elevation. Hailstorms commonly last but a short time, seldom so long as a quarter of an hour.

Doubtless the ordinary cause of a hailstorm is the sudden irruption of an extremely cold air current into a mass of moisture-laden air. The first result of such an irruption would be the rapid condensation of the vapour, and the freezing of the water drops. Then would follow an inrush of air from all sides, caused by the sudden contraction of the cooled air masses. The inrush would cause whirling air-currents (sufficing to account for the occasional formation of very large hailstones by accretion), and thus a still further condensation would take place, but as the freshly arrived air would not be exceedingly cold, like that which caused the first condensation, rain instead of hail would be formed.

Some hailstones have been of enormous size. On May 8, 1832, a mass of ice fell in Hungary, which measured about a yard in length, and two feet in depth, and it is said that in 1849 a mass fell in Ross shire which was nearly twenty feet in circumference. Hailstones are generally composed of alternate layers of clear and opaque ice, surrounding a nucleus of compressed snow. Sometimes they exhibit crystal shaped masses radiating from the centre. Very large hailstones often contain several nuclei, and have a surface bristling all over with small projections.

HALLEY'S COMET. A comet celebrated as the first whose periodic motion was recognised. (See *Comet*.)

HALO (ἅλως, a threshing floor, originally of a round shape.) A luminous ring round the sun or moon, due to refraction of its light through light cloud, fine mist, or minute crystals of snow in the atmosphere. Halos are of prismatic colours. The phenomena of *Parhelion* and *Paraselene*, are due to similar causes.

HALOID. The term haloid salt was given by Berzelius to those salts which consist only of a metal and an electro negative radical or halogen, such as chlorine, bromine, iodine, cyanogen, &c. The term was used in contradistinction to amphid salts, which he supposed to result from the combination of a base with an acid. Thus chloride of sodium would be a haloid salt consisting only of the metal sodium and the halogen chlorine, whilst sulphate of soda would be an amphid salt, as it was supposed to consist of the base soda united with sulphuric acid. In modern chemical nomenclature this distinction is not made, the two classes being considered identical, sulphate of soda being formed on the type of chloride of sodium. (See *Formulæ, Chemical*.)

HAMAL (Arabic.) The star α of the constellation Aries.

HAMMER (Anglo-Saxon and German, *hamer*, Danish, *hammer*.) A heavy mass, usually metallic, attached transversely to a bar of wood or metal. The blow of a hammer derives its utility from expending in an instant the accumulated energy of the continued motion of the heavy mass for an appreciable length of time. For instance, a hammer falling on the head of a nail expends at the instant of contact all its momentum in overcoming the cohesion of the particles of the wood into which the nail is driven. If the duration of the blow is sensibly prolonged, much less effect can be produced in separating the particles. Therefore, wherever the wood into which the nail is driven is but slightly fixed, and is capable of recoiling from the blow, it is impossible to gain the full effect of percussion. (See *Percussion*, *Sledge Hammer*, *Coining Press*.)

HARDNESS. The quality of bodies by which the constituent molecules keep their relative positions, so as to resist any force which tends to change the figure of the body. It is a modification of cohesion, and is intimately connected with elasticity. The hardness of a body does not depend on its density, for we often find very heavy bodies comparatively soft. Thus glass is harder than either gold or platinum, and will scratch the surface of either of these

metals, although the latter is about eight times as dense as glass Again, gold and platinum, although the densest of metals, are softer than iron and zinc, which are comparatively light Hardness and elasticity are usually connected, but not always, thus india-rubber, although very elastic, is at the same time soft (See *Tenacity*, *Elasticity*, and *Compressibility*)

HARDNESS OF MINERALS Estimations of the hardness of minerals are rendered more definite by referring them to Mohr's scale of hardness This consists of the following minerals —

1 *Talc*, common laminated light green variety.
2 *Gypsum*, a crystallised variety.
3 *Calcspar*, transparent variety
4 *Fluorspar*, crystalline variety.
5 *Apatite*, transparent variety
5 5 *Scapolite*, crystalline variety
6. *Feldspar* (orthoclase), white cleavable variety
7 *Quartz*, transparent.
8 *Topaz*, transparent
9 *Sapphire*, cleavable variety.
10 *Diamond*

To determine the hardness of a mineral, ascertain by experiment which of these it will scratch, and which will scratch it, thus if a mineral will scratch calcspar, but not fluorspar, whilst fluorspar will scratch it, its hardness is said to be between 3 and 4

HARMATTAN A periodical wind blowing from the Sahara desert to the Atlantic, between north latitude 15° and south latitude 1°, during December, January, and February

HARMONICS All musical notes so related to a given note, that the numbers of vibrations per second which produce the former are exact multiples of the number of vibrations per second of the latter, are termed the harmonics of the given or fundamental note All the notes produced by exact sub divisions of a stretched string are harmonics of the note produced by the vibrations of the string as a whole The first harmonic of the fundamental note of any string is that produced by half the string, and is the octave of the first, the second harmonic is the dominant or fifth above the first, and is produced by one third of the string, and so on If, for example, the fundamental note be C produced by 512 vibrations per second, the harmonics in order are C′, by 1024 or 2 × 512 vibrations, G′, by 1536 or 3 × 512, C″, by 4 × 512, E″, by 5 × 512 vibrations, and so on The complete series of harmonics contains all the notes of the musical scale

Generally when a string, a bell, or the air of a tube vibrates as a whole, it also vibrates in parts so that several of the harmonics are superposed on the fundamental note, and may frequently, especially with a large bell, be distinguished by the ear The difference of quality in the notes of different instruments is chiefly due to the various ways in which the harmonics of their fundamental note are simultaneously produced (See *Vibrations of Strings*)

HARMONY is that branch of the musical art which treats of the agreement of simultaneous sounds The term is thus used in contradistinction to *melody*, which consists of individual sounds produced in succession

Chord —A group of sounds agreeing according to the laws of musical science, and intended to be produced simultaneously, is called a chord

Common Chord —The simplest chord is the *triad* or *common chord*, consisting of a *root* or *fundamental note*, with its *third* and *fifth*, e g, c-e g, d f a

Chords take the specific names of their root sounds Thus the chord *c–e–g* is called the chord of C, *d f–a* the chord of D

Triads or common chords are *major* or *minor*, according as the interval between them is a major or minor third Thus the triad *c-e-g* is major, because the interval *c–e* is major, the triad *d–f-a* is minor, because third *d–f* is minor

In the major mode the triads upon the *first* (tonic), *fourth* (subdominant), and *fifth* (dominant) degrees of the scale are *major*, and those upon the *second* (supertonic), *third* (mediant), and *sixth* (sub-mediant) degrees are *minor*

Diminished Triad —If the *seventh* degree of the scale be taken as the root of a triad, we get a triad which is neither major nor minor In both the latter the interval between the root and fifth is *perfect*, but in the triad upon the seventh of the scale, while the third is minor as in the minor triads, the fifth is *imperfect* or *diminished*, hence this triad is called the *imperfect* or *diminished triad*

In the minor mode the triads upon the *first* and *fourth* degrees are *minor*, those upon the *fifth* and *sixth* are *major*, those upon the *second* and *seventh* are *diminished*, and the remaining triad, that upon the *third*, viz, *c–e–g* ♯ in A minor, consisting of a root, a *major third*, and an *augmented fifth*, is called an *augmented triad*

Major and Minor Modes —On comparing the two modes it will be seen that major triads are more numerous in the major than in the minor mode, and that in the former they occur upon each of the principal degrees, viz, the *first*, *fourth*, and *fifth*, whereas in the latter, the triad on one only (the fifth) is major, the other two carrying minor triads This circumstance,

together with the fact that two of the remaining triads are diminished, and that the other is distinguished by the presence of an augmented interval of harsh and unpleasant effect, will serve to explain in a measure the wide difference that exists between the two modes in their effect upon the ear

Chord of the Seventh.—The chord next in order of importance to the triad is the *chord of the seventh*, formed by adding to the triad a fourth sound at the interval of a seventh from its root, e g, *c–e–g–b*, *d–f–a–c*, &c

Dominant Chord.—There are many varieties of the chord of the seventh, by far the most important being that, whose root is the *fifth* or *dominant* of the scale, and which is called from this circumstance the *Chord of the Dominant Seventh*, or briefly the *Dominant Chord*, e g, *g–b–d f* in the scale of C (major or minor)

The *dominant chord* consists of a *root* with its *major third*, *perfect fifth*, and *minor seventh*, and is the same in the minor as in the major mode It will be seen further also that the same combination cannot be formed upon any other degree of either the major or minor mode, nor can it be obtained from any other scale than that to which it belongs This latter proposition may be readily proved as follows Take the chord given above, viz, *g-b-d-f*, the dominant chord of C major Because it contains the note F it cannot belong to any of the scales with sharps in their signature, since in all these the F is sharp, and since it contains the note B, it cannot be obtained from any of the scales with flats in their signatures, as in each of these the B is flat The same proof applies equally to the minor keys

It follows from this, that the dominant chord is always a sure indication of the key of the piece in which it occurs It does not, however, indicate the mode To determine this it is necessary to look also at the tonic triad, which, as we have already stated, is major or minor according to the mode

Chord of the Ninth.—If to the dominant chord a fifth sound be added, a third above the seventh, and consequently a ninth above the root, we obtain a *chord of the ninth*, e g

g–b–d–f a in C major,
and *g–b–d f–a* ♭, in C minor

That obtained from the major scale is called the *chord of the major ninth*, that from the minor scale the *chord of the minor ninth*

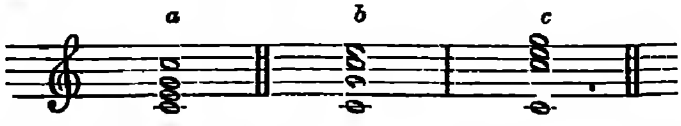
Doubling.—If a sound of a chord is produced by more than one voice or instrument either in the unison or the octave, it is said to be *doubled* Any note of a chord may be thus doubled, but as a general rule the *third* and *seventh*, being by themselves of a more striking character than the other intervals, are the ones most frequently exempted from doubling

Omission.—It also frequently happens that one or more intervals of a chord have to be omitted Here again it is the third and seventh, together with the root of the chord of the seventh that can be least readily dispensed with, as they are the most characteristic intervals of the chord If the root of the dominant chord be omitted, we get the diminished triad on the seventh of the scale before described

Thus from the dominant chord *g–b–d–f*, by omitting the root *g*, we get the diminished triad *b–d–f*

Diminished Seventh. Again from the *chord of the minor ninth*, by omitting the root, we get a chord of the seventh consisting of a *diminished triad* and a *diminished seventh*, e g, *b d–f a* ♭ from *g–b–d–f–a* ♭ This is called the *chord of the diminished seventh*, and forms very important functions in modern music on account of the facilities it affords the composer in effecting changes of key

Position.—In the preceding remarks, we have considered chords in the light of the natural or normal arrangement of their sounds, i e, as they stand in the order of thirds from their root upwards But any note of a chord may appear in the highest part without affecting the nature of the chord The variations then produced are termed *positions* If the root is at the top as well as at the bottom, the chord is in its *first position*, Fig *a* If the third appears at the top the chord is said to be in its *second position*, Fig *b*. If the fifth is at the top, the chord is in its *third position*, Fig. *c*.

Fig.

Inversion.—Chords are further varied in effect, though not in their essential nature, when any other interval than the root appears in the lowest part. These variations in the arrangement of the notes of a chord are termed *inversions*.

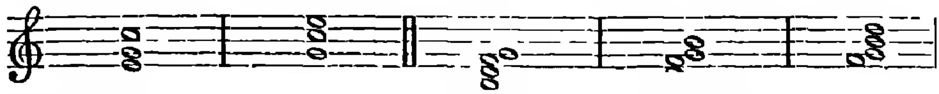
If the *third* appears in the lowest part, the chord is said to be in its *first inversion* Fig *a* shows the first inversion of the common chord, *aa* the first inversion of a chord of the seventh

If the *fifth* appears in the highest part, the chord is said to be in its *second inversion* Figs *b*, *bb*

If the *seventh* appears in the highest part, the chord is in its *third inversion*, Fig *c*

a *b* *aa* *bb*

Fig



Chord of the Sixth —These various inversions have special names derived from the intervals which their more important sounds form with the lowest sound in each case Thus the most important sounds of the triad are its *root* and *third* In the first inversion the latter is the lowest sound, and the former makes with it the interval of a *sixth* hence the first inversion of a common chord is called the *chord of the sixth*

Chord of the Sixth and Fourth —The second inversion of the common chord is, for similar reasons, called the *chord of the fourth and sixth*, or briefly the *six four chord*

Chord of the Fifth and Sixth —The most important sounds of the chord of the seventh are its *root* and *seventh* In the first inversion of this chord the root and seventh form the intervals of a *fifth* and *sixth* with the lowest sound, hence this inversion is called the *chord of the fifth and sixth*, or briefly the *six five chord*

Chord of the Third and Fourth —In the second inversion the root and seventh, with the lowest sound, forms intervals of a *third* and *fourth*, this inversion is accordingly designated the *chord of the third and fourth*, or briefly the *three four chord*

Chord of the Second —In the third inversion the seventh is the lowest sound, and because the root forms with it an interval of a *second*, the chord is called a *chord of the second*

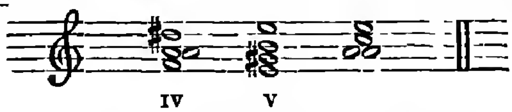
Inversions of the chords of the ninth are so rarely used, that it has not been deemed necessary to supply them with similar independent designations

Any interval of a chord may be occasionally raised or lowered a semitone In this way, combined with inversion, certain most pleasing combinations have been produced, some of which have become so important as to merit special names The chief of these are certain forms of the sixth, which we must not omit to describe

The Italian Sixth —If we take the minor chord on the fourth degree of the minor scale—viz *d f a* in A minor, and raise the root a semitone, *e g*, *d♯ f-a*, we get a chord with diminished third as well as a diminished fifth, and which is therefore called a *doubly diminished chord* The first inversion of this chord is called the chord of *the Italian sixth*

Original Chord Chromatically altered Inverted

This chord is of frequent occurrence in music in the minor mode Its derivation is shown by the fact that it is invariably followed by the dominant chord of the scale from which it is said to be derived. Thus—

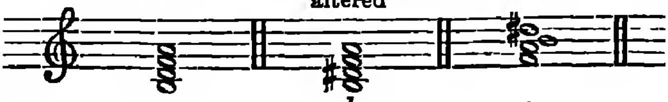


IV V

The German Sixth —If the chord of the seventh on the second degree of the minor mode be taken, Fig *a*, and its third be chromatically raised, Fig *b*, and then the chord be placed in its second inversion, Fig *c*, we have what is called the chord of *the German sixth*

Original Chord Chromatically altered Inverted.

Fig

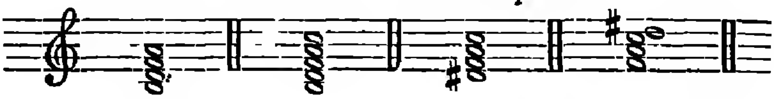


a *b* *c*

It will be seen that, by the omission of its root, this chord becomes identical with that of the Italian sixth

The French Sixth.—If the root of the preceding chord be omitted, and the ninth added—

Fundamental Chord | With added Ninth | Root omitted and Third sharpened. | Inverted



we get an agumented chord of the sixth and fifth, which is sometimes called *the French sixth*

The other inversions of these chords are seldom used

Close and Dispersed Harmony—If the sounds of a chord are situated as close together as possible the harmony is termed *close*, if they are at greater distances from each other, the harmony is said to be more or less *extended* or *dispersed*

In a succession of chords it is very material that they shall be connected with one another This may be affected by so arranging that each succeeding chord has one or more notes in common with its predecessor, or that their roots are always related to each other

Fig *a*.

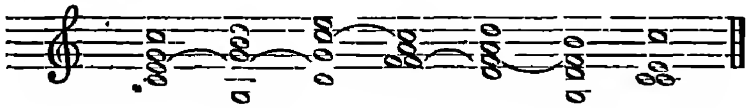
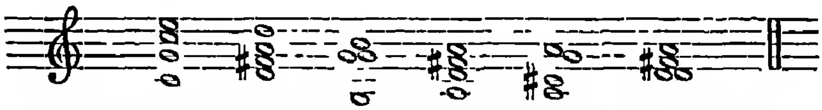


Fig *b*



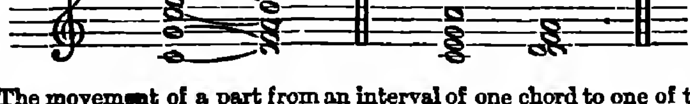
In Fig *a* the first three chords have the note G in common, the third and fourth have the note C in common, the fourth, fifth, and sixth the note F, the sixth and seventh the note G The succession is the more firmly welded when the notes which consecutive chords possess in common are produced by the same voice or instrument, or, in other words, when they are in the same part

In Fig *b*, though the first pair of chords have no note in common, they are nevertheless closely related, the first being the tonic harmony of the key of C, and the second which is the triad upon the dominant of the key of G, the nearest relative of the key of C The third chord is the triad on the tonic of G, and the fourth is the second inversion of the dominant triad of the same key (G), and the fifth chord not only has two sounds in common with its predecessor, but is at the same time the dominant chord of the nearest relative of the key of G, namely, the key of D major

Consecutive Fifths and Octaves—In moving a number of voices from chord to chord, care must be taken to avoid what are termed *false progressions* No two parts should be allowed to move in fifths or octaves, as in the following figure,

where the upper and lower parts move in *octaves*, and the lower and one of the inner parts move in *fifths* Such progressions are termed *consecutive fifths* and *octaves* They may be avoided either by changing the *position* of the chords, or by otherwise altering the movement of the parts, thus

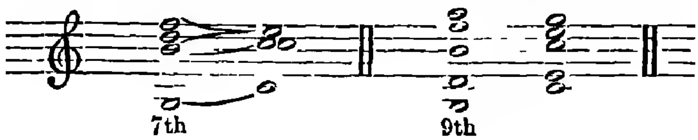
or



Resolution—The movement of a part from an interval of one chord to one of the next following chord is called a *resolution.* The first interval is said to resolve itself into the latter. Certain

chords require that their intervals shall be resolved in a particular direction, and to certain intervals of the following chord This is particularly the case with the dominant chord, and the chords of the ninth derived from it In the resolution of these chords the general rule is for

The seventh to descend one degree,
The third to ascend one degree,
The fifth may move freely,
The root to move to the root of the next chord,
The ninth to follow the seventh downwards one degree



The same rule applies more or less to the inversions of the dominant chord, chord of the ninth, and diminished triad

Modulation —It very rarely happens that a composition remains its entire length in the key in which it commenced, and to which it chiefly adheres, and which is called on this account the *key of the piece*, or the *principal key*

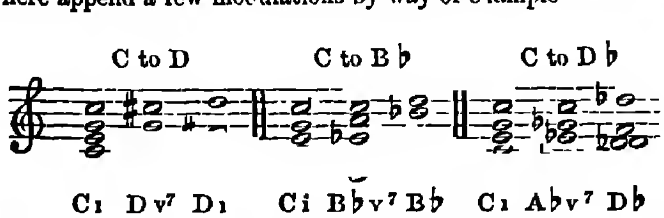
A change from one key to another is called a *modulation* If the new key is continued for a brief space only, and the idea of the principal key is not wholly obliterated from the mind, the modulation is said to be *transient* If the new key continues for any length of time, the modulation is said to be *confirmed*

The keys generally selected to follow the principal key are those most intimately related to it These are, first, the keys of the *dominant* and *sub-dominant*, next, the relative minor keys of the *tonic*, *dominant*, and *sub-dominant* If still further modulation is required the keys most nearly related to these are entered Pieces in a major key generally modulate first into the key of the dominant Those in a minor key move most frequently into its relative major

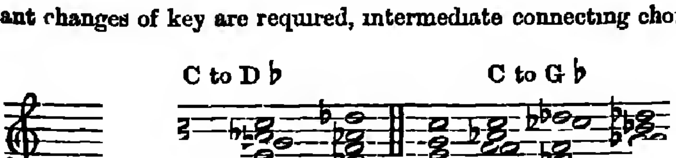
When a composition follows the above scheme of modulation, its modulation is said to be *gradual* or *natural*

Sometimes for the sake of effect a sudden change is effected into a more distant key In this case the modulation is termed *abrupt*

Modulation is effected by introducing sounds characteristic of the key into which it is desired to enter Now, as the dominant chord is the most certain indication of the key to which it belongs, it is found to be the most potent agent for effecting modulation If, for example, in a piece in the key of C major, the chord *d f ♯ a-c* made its appearance, we should know at once that a modulation was being effected into the key of the dominant G If the combination *e g ♯ b d* were heard we should conclude that a modulation was taking place into the relative minor A We here append a few modulations by way of example —

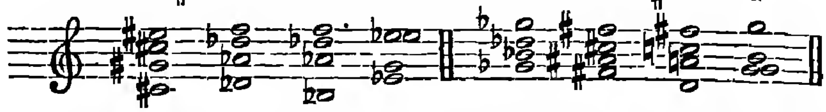


If very distant changes of key are required, intermediate connecting chords are introduced.



Or enharmonic changes may be made, that is, the same sounds may be represented in the notation of their enharmonically parallel sounds, thus —

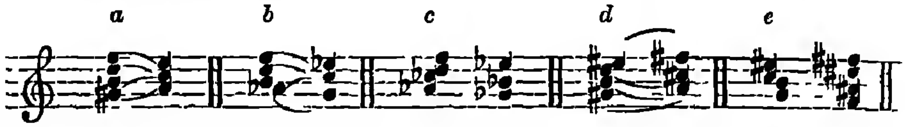
a C♯ or D♭ to E♭ *b* G♭ or F♯ to G



At *a*, speedy modulation is effected between the two very distantly related keys of C♯ and E♭, by simply substituting for the first chord of C♯ its enharmonically parallel chord D♭, which is much more closely related to the required key An almost equally distant modulation is affected in a similar manner at *b*

The chord of the diminished seventh affords a ready means of getting from one key to another, with the assistance of an enharmonic change, although it is not so pronounced and decisive in its effect as the dominant chord Owing to the peculiar relationship of its sounds, it may by the successive substitution of their enharmonic parallels be made to point to as many as four different and distantly related keys

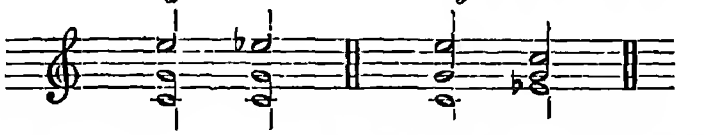
a *b* *c* *d* *e*

Fig

At *a* we have the diminished seventh chord on the seventh degree of A minor resolving itself into the tonic chord of the same key, at *b* we have the same sounds, only by reason of the enharmonic change, A♭ instead of G♯, they point to the key of C minor, at *c* we have the same chord, but with two of its sounds subjected to an enharmonic change, pointing to the key of E♭ minor, at *d* in a similar change of three of its sounds it appears as belonging to the key of F♯ minor, and at *e* by an enharmonic change of all its sounds it points to the key of D♯ minor

False Relation—When two successive chords contain the same degree of the scale, but chromatically varied or lowered in the second chord, the chromatic alteration should be made in the parts or by the voice which sounded the original note, as at A and not as at B

a *b*

Fig

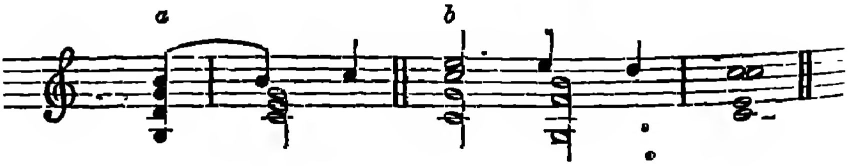


The non-observance of this rule produces what is called a *false relation* between the parts which is disagreeable to the ear This was a great bugbear to the ancient theorists, who termed it "mi contra fa" There are certain cases in which, when the effect is modified by surrounding circumstances, its use may be justifiable, but as a general rule it is better avoided altogether

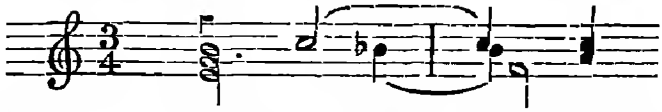
The progression of a series of chords may be considered, in fact is always most properly considered, as the simultaneous progression of as many distinct parts or melodies as there are notes in the several chords In this view of the progression of parts in harmony several very important and interesting features find their most natural explanation

Suspension.—We have hitherto considered that the several parts progress from chord to chord simultaneously But a great variety of very charming effects are obtained by the *dis simultaneous* progression of the parts One of the most important of these is the *suspension* A note is said to be suspended when it is continued from one chord to another to which it does not properly belong, and into a proper interval of which it must finally resolve itself.

a *b*

Fig

At *a* the note B is suspended during the first half of the second chord, and resolves itself upwards into the note C This is called a suspension *from below* At *b* the note E is suspended during a portion of the second chord, and resolves itself finally downwards into a note of that chord This is called a suspension *from above* It will be noticed that the suspended note makes its appearance as a proper interval of the previous chord This previous appearance is called by theorists the preparation of the *suspension*

Anticipation —Sometimes during the continuation of a chord, a sound having no connection with it, but belonging to the succeeding chord, is introduced without any sort of preparation

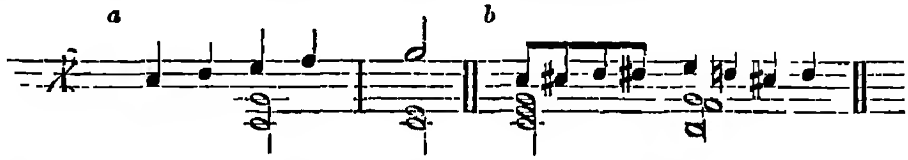


In the above example the note C in the first bar has no connection with the chord *c-g-b*, but belongs to the following chord of the fifth and sixth *c-g b ♭ c* Such a premature appearance of a sound is called an *anticipation*, and the sound itself is called an anticipated sound

Pedal Note —Sometimes a sound of a chord is continued during the passage of a series of other chords to which it is quite foreign, and until a chord occurs to which it does belong Such a sound is called a *pedal note*, the whole passage in which it occurs a *pedal passage*

Passing Notes —In passing from one interval of a chord to the next the intermediate note or notes may be touched The notes thus introduced are called *notes of transition* or *passing notes*

Tr



The notes D and F (Fig *a*) in the above example are passing notes

Passing notes may be diatonic or chromatic diatonic, and they may be introduced to the number of three or even four in succession Fig *b*, in which the notes C ♯, D, D ♯, and E, are passing notes

Thorough Bass —Thorough bass is a kind of musical shorthand in which the harmony of a composition is indicated by certain figures placed above or below the bass part

If no figure appears over a note it is understood that the common chord on the bass note is to be played. This chord is also figured by 3, $\frac{5}{3}$, $\frac{8}{\frac{5}{3}}$, etc

6	signifies that a chord of the		sixth is to be played	
$\frac{6}{4}$ or $\frac{4}{3}$	,,	,,	sixth and fourth is to be played	
7	,,	,,	seventh	,,
$\frac{6}{5}$ or $\frac{5}{6}$	,,	,,	sixth and fifth	,,
$\frac{3}{4}$ or $\frac{4}{3}$	,,	,,	third and fourth	,,
2	,,	,,	second	,,
9	,,	,,	ninth	,,

A chromatic sign before a figure has the same effect as though it were placed before the note represented by the figure When the third from the bass note is to be thus altered, the chromatic sign is written without a figure Suspensions, anticipations, and passing notes are indicated by figures showing the interval they severally make with the bass note.

The above are the chief elements of thorough bass notation, several other details are introduced which it is not necessary here to enumerate As a system of notation it is very deficient in that it does not represent the number of parts that are to be used, nor the rhythmical divisions. Its great use consists in the fact that it enables a composer to convey quickly to paper a rough skeleton of his thoughts while they are fresh on his mind It is not, however, so much used now as in former times

HARTON COLLIERY EXPERIMENT See *Earth*

HARVEST MOON The full moon which falls nearest to the autumnal equinox Near the autumnal equinox the half of the ecliptic visible at sunset makes the least possible angle with the horizon Thus, when the moon is nearly full, or rising as the sun sets, she is travelling at the least possible angle with the horizon, and thus on successive nights rises nearly at the same time, or rather at times separated by the least possible intervals.

HEAT. When we touch anything which, in ordinary language, is said to be *hotter* than ourselves we experience a peculiar sensation, familiarly known as *heat*. The term is derived in all probability from the Sanskrit *indh*, to kindle, through the Greek αιθω, the Latin *æstus*, and the old German *eit*. It is also closely related to the Gothic *haitan*, the Frisian *hytte*, the Icelandic *hita*, and the Anglo-Saxon *haeto*. These words are all related, more or less directly, to *æstus*. "*Æstus*," says Vossius in his *Lexicon Etymologicon*, "*est commotio, vel in igni, vel in aqua, vel in animo; omnis autem commotio fervorem gignit*." Inasmuch as heat is now considered to be a motion belonging to matter, not, as was formerly believed, a kind of matter itself, it will be seen that the word *heat* is peculiarly appropriate for designating the science. We must regard heat as a motion appertaining to matter—a motion of the infinitely small particles, or atoms, or molecules, of which all matter is composed. This motion, when communicated to the brain through the intervention of the particles of the cerebro spinal nerves, produces in us the sensation by which heat is familiarly recognised and known; and when communicated to inanimate matter it produces various changes, which will be described in detail elsewhere. Till within the last twenty years, heat was almost universally considered to be a kind of very subtle matter, capable of passing, in its material form, from one substance to another. Nevertheless, from the earliest times, certain philosophers have expressed their opinion that heat is not material, but rather a quality of matter. The Stoics regarded fire as the active principle of the universe, because it possesses innate motion. Epicurus considered heat as an effluxion of minute spherical particles possessing rapid motion, and capable of insinuating themselves into the densest substances in virtue of their smallness and the rapidity of their motion. Lucretius, who followed Epicurus somewhat closely, maintained that both the light and heat of the sun are the result of the vehement motion of primary particles ("*primi minuti*"). Aristotle appears to have regarded heat rather as a condition of matter than as matter itself. By the ancients generally, fire (under which term was included both light and heat) was considered the active agent of the universe; it was the *force* exercising itself upon *matter*. The function of fire is well signified in the story of Prometheus, who was fabled to have stolen fire from heaven, and therewith vivified mankind. Fire was the *anima*, while the inferior elements, air, water, and earth, together constituted the *corpus*. The views of the ancients regarding the nature of heat appear to have been somewhat generally adopted during the Middle Ages. Cardanus (*b* 1501) frequently speaks of "*motus ignis*" and "*motus caloris*." Robert Fludd, writing in 1617, affirms that heat is the ultimate effect of the action of light, resulting from the motion of material particles. Telesius of Cosenza asserted that heat is the cause of motion, cold of rest, and that the interaction of these incorporeal principles produces all the phenomena of the universe. Francis Bacon was one of the first to deny the elemental nature of fire, by affirming that it is "merely compounded of the conjunction of light and heat in any substance." Elsewhere, he defines heat as "not a uniform expansive motion of the whole, but of the small parts of a body; and this motion being restrained, repulsed, and reflected, becomes alternating, perpetually hurrying, striving, struggling, and irritated by the repercussion, which is the source of the violence of flame and heat." Again, he says, "Heat is a motion, expansive, restrained, and acting in its strife upon the smaller particles of bodies." As an example of the production of heat by the motion of a mass, he mentions that a piece of metal, when hammered, becomes hot, and if the hammering were continued, would probably become red-hot—an effect which may readily be produced, and an example which, to this day, appears in our text-books. Descartes, who has made many most pertinent remarks regarding heat in his *Principia Philosophiæ*, asserts that a nail which is being driven into a block of wood does not grow hot until after it has been forced home by the hammer, because heat is the motion of the insensibly small parts of matter, not of masses; and so long as the nail itself is capable of moving, the force of the blow is expended in producing the motion of a mass, not in moving the minute particles of the body. John Locke seems to have fully recognised the theory which considers heat as a motion of matter. "Heat," he says, "is a very brisk agitation of the insensible parts of the object, which produces in us that sensation from whence we denominate the object hot; so that, what in our sensation is *heat*, in the object is nothing but *motion*." Thus far we have spoken of the views of certain old writers who regarded heat as motion; but, side by side with their dogmas, there flourished an hypothesis which affirmed that heat is substantial. Towards the middle of the seventeenth century there arose a theory which, for more than a century, profoundly influenced the scientific world, and which proposed to account for various phenomena by the absorption or rejection of "materia aut principium ignis, non ipse ignis"—the *matter* or principle of fire, not fire itself. This was known as the theory of Phlogiston (see *Phlogiston*), and was specially applied to chemical phenomena. The *materia ignis*, or φλογιστον, was supposed to be a subtle, invisible matter, capable of readily passing from one substance to another, and of producing various changes, according as it was accumulated in, or separated from, different substances.

From this arose a very extended theory of materialised heat, which was, in one form or other generally adopted during the whole of the last, and far into the present century. We see therefore, that there had gradually arisen side by side two distinct theories in regard to the nature of heat, the one regarding it as matter, and calling it Phlogiston or Caloric (*calor*, heat from *caleo*, κηλοω), and known as the *Material Theory* (*materia*, matter), the other regarding it as a rapid motion of the small particles or molecules (*molecula*, a small mass) of matter, and known as the *Kinetic Theory* (κινησις, motion), or the *Dynamic Theory* (δυναμις, force), or as *Thermo-dynamics*.

At the close of the last century the material theory was universally adopted, and we have now to consider certain experiments which were then made which proved its fallacy and paved the way for its downfall in our day. In the various examples in which heat is produced by mechanical means, such as friction, compression, and percussion, the materialists accounted for the development of heat by asserting that the act of friction, &c., altered the capacity for heat of the substance so acted upon. A nail becomes hot when it is hammered, they said, because its particles are compressed and the heat as it were squeezed out, like water from a compressed sponge; the unhammered metal has a greater capacity for heat, or capability of holding it than the hammered metal. They denied the possibility of producing *new heat*, asserting that the quantity of heat in the universe is a constant quantity which cannot be increased or diminished, and which manifests itself only when passing from one substance to another. Again, it was well known that certain different substances possess a greater capacity for heat than others, for example, that more heat is required to raise one pound of water 10° than to equally heat one pound of mercury; and the materialists explained this by saying that the water had a greater power of storing away heat than mercury. In 1797, Count Rumford, while superintending the boring of cannon in the Arsenal of Munich, was surprised to find the very great extent to which a gun became heated during the process, and that the metallic shavings separated by the borer were yet more heated. He was led to examine this result by the assertions of those who adopted the material theory of heat, for if, as they affirmed, the heat of friction results from an altered capacity for heat in the substances submitted to friction, it follows that all the heat developed in the cannon and the metallic shavings must have resulted from the altered capacity for heat of a few ounces of metal shavings. But this appeared incredible; moreover Rumford found on experiment that the metal shavings had precisely the same capacity for heat as the solid metal of the cannon. He then constructed a special apparatus for the production of heat by friction, in which a blunt steel borer was caused to revolve by horse-power, and to press against the bottom of a metal cylinder. This cylinder was surrounded by a second one in which was placed 2½ gallons of water possessing a temperature of 60° F. Thus the heat produced by the friction of the blunt borer against the inner cylinder was communicated to the water in the outer cylinder. One hour after the commencement of revolution of the borer, the temperature of the water had risen 47°, that is to 107°; during the next half-hour it rose to 142°; at the end of two hours to 178°, and in two hours and a half the whole mass of 2½ gallons of water actually boiled by the heat of friction. Here then we have an example of the continuous production of heat.

"It is hardly necessary to add," he writes, "that anything which any insulated body or system of bodies can continue to furnish *without limitation* cannot possibly be a material substance; and it appears to me to be extremely difficult, if not quite impossible, to form any distinct idea of anything capable of being excited, and communicated in these experiments, except it be *motion*." This was the first and most decisive blow which was aimed at the then dominant material theory of heat. A few years later Sir Humphry Davy proved conclusively the immateriality of heat. It was well known that water at the freezing temperature has a greater capacity for heat (or more heat stored up in it, as the materialists said,) than ice at the same temperature. (See *Latent Heat*.) To liquefy ice a large amount of heat is required before the temperature of the resulting water commences to rise. "Now," said Davy, "if I, by friction, liquefy ice, a substance will be produced which contains a far greater absolute amount of heat than the ice; and in this case it cannot with any show of reason be affirmed that I merely render sensible heat, which had been previously insensible in the frozen mass. Liquefaction in this case will conclusively demonstrate a *generation* of heat." Accordingly he rubbed together two pieces of ice placed both in air and in a vacuum, and surrounded by a freezing atmosphere; the ice was liquefied, and the direct generation of heat by mechanical means was thus conclusively proved.

Although the falsity of the material theory of heat was proved thus early in the century, it was by no means abandoned; indeed, the dynamic theory had scarcely a supporter, and this state of things continued until it was proved that a certain definite amount of mechanical work corresponds to a certain definite amount of heat, and *vice versa*, that is, until the determination

of the so-called *mechanical equivalent of heat* This was commenced about 1842 by Dr Julius Mayer, of Heilbronn, and in 1843 by Mr Joule, of Manchester, and the results obtained (by perfectly distinct methods) proved that 772 foot pounds of mechanical work must be expended in order to produce one unit of heat, in other words, that 1 lb of water falling under the influence of gravity through 772 feet, has its temperature raised 1° F when it comes into collision with the earth (See *Mechanical Equivalent of Heat*) We have here, then, proof of the direct conversion of the motion of a tangible mass, that is mechanical work, into the motion of intangible molecules, that is heat, and we have the precise relative values in their respective units The converse of this also takes place, for a given amount of heat truly represents, and is capable of being converted into a certain definite amount of mechanical work The extension and application of this important demonstration will be found in various portions of this work

The science of heat, properly so called, is younger than nearly all the physical sciences, and this arises from the fact that until late in the last century heat was regarded simply as a chemical agent (See *Caloric*) There were no separate treatises on heat, but a chapter was always devoted to it in works on chemistry In one sense the theory of Phlogiston (which see) is essentially a heat theory, but it has always been regarded as a chemical theory, because heat plays so important a part in many chemical operations that the agent became hidden, so to speak, in its applications *Pyrotechnia* (πῦρ τέχνη) was indeed one of the many names by which chemistry was known "car, en effet," says Lemery, "c'est par le moyen du feu qu'on vient à bout de presque toutes les opérations chymiques" In old scientific works we frequently meet with such words as *calcinatio, ignitio, cinefactio, reverberatio, desiccatio, sublimatio,* and *distillatio,* and the applications of heat to chemical processes are now more numerous than ever S'Gravesande, writing in 1742, gives 45 pages to heat in his *Physices Elementa Mathematica,* yet it was more generally made a part of chemical treatises until the present century, when separate works on the subject infrequently appeared Of recent works we may specially mention Tyndall, "On Heat considered as a Mode of Motion," Balfour Stewart "An Elementary Treatise on Heat," A Cazin, "La Chaleur," and Clausius, "On the Mechanical Theory of Heat" The various phenomena connected with heat will be found discussed under separate headings in this Dictionary (See specially *Absorption of Heat, Calorescence, Conduction, Convection, Ebullition, Expansion, Latent Heat, Liquefaction, Radiant Heat, Solidification, Specific Heat, Temperature, Thermometry, Vaporization*)

HEAT, ANIMAL See *Animal Heat*

HEAT, ATOMIC See *Atomic Heat*

HEAT-ENGINE. A machine in which heat is transformed to mechanical force Such a machine consists of a source of heat, a receiver of heat or refrigerator, and a means of conveying heat between them, and it produces work while heat passes from the source to the refrigerator By means of a conception due to Carnot (see *Carnot's Function*), Sir William Thomson has determined the amount of work which can be produced by a perfect heat engine of any kind The fraction of the heat, which is converted into work, is directly proportional to the difference of the temperatures of the source and refrigerator, and inversely proportional to the temperature of the source If we take the number of degrees above the absolute zero of temperature, the fraction of heat available for work in a perfect engine is *equal* to the range of temperature, divided by the temperature of the source reckoned from the zero of absolute temperature For example, suppose the temperature of the source of heat to be 142° C, and that of the refrigerator 69° C, and the absolute zero of temperature −273° C, then the fraction of the heat expended, which is available for work, is 142−69, divided by 142+173 or one fifth Again, suppose the heat to be supplied to this machine, by burning a material, a pound of which yields, on combustion, heat equivalent to 10,000,000 foot pounds, then the work done by the engine for every pound of fuel burnt will be 2,000,000 foot pounds It is evident from this law that the greater the difference of the temperatures of source and refrigerator, the more economical will be the engine, and as in general the lowest temperature will be that of the surface of the earth, and therefore constant, it follows that the greatest economy is secured with the highest attainable temperature In the steam-engine, worked with saturated vapour, the temperature of the steam will depend on the pressure under which it is produced, and is therefore limited by the strength of the materials employed In the steam-engine, worked with steam to which additional heat has been communicated after it has left the boiler, and while not in contact with water, the limit depends on the temperature at which the steam acts chemically upon the metals containing it, and also on the power of these metals to resist the action of heat. The same limits to high temperature occur with hot-air-engines, as with steam-engines (See *Steam-Engine, Hot-Air-Engine, Gas-Engine*)

HEAT OF CHEMICAL COMBINATION A matter of the highest importance, both practical and theoretical, is the evolution of heat during chemical combination. Ordinary com

bustion, as when heat is produced by the burning of coal or wood in air or oxygen, is a very familiar example, another is found in animal heat, which arises from the conversion of the carbon contained in the food, into carbonic acid gas by the oxygen which is taken into the lungs, a third case is found in what is called by Liebig *Eremacausis* (ἤρεμος, slow, καῦσις, a burning), as when moist leaves, damp hay, or other organic matter, slowly oxidising in the air, become heated often very intensely, heat is also well known to be given out when a metal, such as zinc, is acted on by an acid, and it is true that no chemical combination, if we exclude from chemical combination cases of mere solution, can go on without the evolution of heat. Even when cold is produced by solution, it is due to alteration in physical condition, generally to a change of a solid or solids into a liquid

The determination of the heat due to chemical combination is by no means easy Were it sufficient to burn a pound of carbon or of hydrogen in a sufficient supply of oxygen or chlorine within a calorimeter, and then note the increment of heat, the problem would perhaps not present much difficulty, but the properties of the new compounds formed as a rule differ widely from those of the elements of which they are composed, thus a solid may become gaseous as carbon in carbonic acid, or two gases a liquid, therefore, the specific heat and the latent heat may change, and it is very difficult to ascertain the effect of these alterations upon the observed increase of heat The experimental examination of the question was first undertaken by Lavoisier, who was followed by Dalton, Davy, Dulong, Desprets, Hess, the most recent results are those of Andrews, and of Favre and Silbermann, and of these we shall give a brief account

We must refer the reader to the original memoirs for an account of the apparatus used, and of the various precautions taken in performing the experiments, it is sufficient to say that both used calorimeters in which the combination was caused to take place within one vessel immersed in a second, which was filled with water, extraordinary precautions being taken to avoid loss by radiation That of Andrews is described in the *Philosophical Magazine*, May 1848, that of Favre and Silbermann in the *Ann de Chimie*, III, xxxiv, xxxvi, xxxvii Afterwards Favre and Silbermann used a mercury thermometer with a very large bulb, having a hollow opening into it within which the substances to be experimented on were placed

As might be expected from the known laws of energy, the combination of given weight, one element with an equivalent quantity of another, gives rise to a definite amount of heat, both elements being in a given condition The following table, quoted from Miller's Elements of Chemistry, gives concisely what are called by Favre and Silbermann the *calorific equivalents* of the various elements when combined together "The numbers given indicate the quantity of heat evolved by the union of equivalent quantities of oxygen, chlorine, bromine, iodine, and sulphur with each element, taking as the standard of comparison the number of grammes of water at 0° C, which would be raised to 1° C by the combustion of one gramme of hydrogen in oxygen" The numbers for the various elements are calculated from their *equivalent numbers*, and not from their *atomic weights* The observers are Andrews, Favre and Silbermann, and Dulong Those numbers to which an asterisk is prefixed are calculated by indirect methods—

CALORIFIC EQUIVALENTS OF VARIOUS ELEMENTS (O = 8)

Elements	Observers	Oxygen	Chlorine	Bromine	Iodine	Sulphur
Hydrogen,	F and S	34462	23783	*9322	*−3606	*2741
Carbon,	"	24240				
Sulphur,	"	17760				
Phosphorus,	A	36072				
Potassium,	A		104476			
Do	F and S		*100960	*90188	*77268	*45638
Sodium,	"		94847			
Zinc,	A	42282	50658	40640	26617	
Do	F and S	*42451	*50296			*20940
Iron,	A	33072	32695	23833	8046	
Do	F and S	*37828	*49651			*17753
Tin,	A	33519	31722			
Arsenicum,	"		24992			
Antimony,	Dulong	47000	A 30401			
Copper,	"	19152	30404			
Do	F and S	*21885	*29524			*9133
Lead,	"	*27675	*44730	*32802	*23208	*9556
Silver,	"	*6113	*34800	*25618	*18651	*5524

As an example of the use of this table, it appears from it that the burning of one gramme (or one pound) of hydrogen in oxygen to form water, would give rise to as much heat as would raise

the temperature of 34462 grammes (or pounds) of water from 0° C to 1° C. Again 32·75, being the equivalent number for zinc, the combination of 32·75 grammes (or pounds) of zinc, with a sufficient quantity of oxygen (8 grammes or pounds) to oxidise it completely, gives rise to as much heat as would raise 42282 grammes (or pounds) of water from 0° C to 1° C, while the combination of the same weight of zinc, with an equivalent quantity of chlorine (35·5 grammes or pounds), would evolve enough heat to raise 50658 grammes (or pounds) of water from 0° C to 1° C

Favre and Silbermann proved, by examining carbon, sulphur, and phosphorus, that equal weights of the same body, when in different allotropic conditions, do not evolve the same quantities of heat during combustion, and also that, in the case of compound bodies burned, the condition as to form before combustion has an influence on the amount of heat given out

Andrews determined, in a large number of cases, the quantity of heat evolved during the precipitation of one metal from its salts by another metal His numerical results will be found in his paper on the subject in Phil Trans, 1848 He came to the following important conclusions —

(1) That when an equivalent of one metal is displaced by an equivalent of another metal, the amount of heat given out is the same, whatever be the acid of the salt, provided that the former metal is in all the salts in the same state of oxidation, but that if different precipitating metals be used, the quantities of heat evolved are different

(2) That the following is the order of the metals arranged, so that the first evolves most heat when used to precipitate the metal at the opposite extremity of the list —

Zinc	Mercury
Iron	Silver
Lead	Platinum.
Copper	

It will be noticed that this is the electro-chemical order of the metals Each is electro positive with respect to those which follow it

(3) If there be three metals, A, B, C, such that A will displace B and C from their salts, and B will displace C from its salts, then the heat evolved, when an equivalent of A displaces an equivalent of C, is equal to that given out when an equivalent of A displaces an equivalent of B, together with that given out, when an equivalent of B displaces an equivalent of C

Again, we observe here an electrical analogy, for if there be three metals, A, B, C, arranged in order, the electromotive force between A and C is equal to that between A and B, together with that between B and C

For farther particulars on this subject we must refer our readers to the papers we have already mentioned, to a memoir by Professor Andrews, published in the Transactions of the Royal Irish Academy, 1841, and to a "Report on the Heat of Combination," in the Reports of the British Association for the Advancement of Science, 1849

HEAT OF CURRENT See *Current, Heating Effects of*

HEAT, SOURCES OF The sources of heat may be ranged under three separate heads—firstly, *extra-terrestrial sources*, including the sun, moon, and stars Secondly, *terrestrial sources*, including the various actions by which heat is generated on the earth, such as mechanical action, chemical action, electricity in motion Thirdly, *intra terrestrial sources*, that is, the innate heat of the earth, manifested to us by the eruptions of volcanoes, hot springs, &c

1 *Solar Heat* First and foremost is the solar heat, from which all the heat of the moon, and almost all the heat of the earth, is supplied The amount of heat emitted by the sun has been measured with considerable accuracy both by Sir John Herschel and by M Pouillet, and their results agree very closely, for the former finds that the effect of a vertical sun at the level of the sea is sufficient to melt 0·00754 of an inch of ice per minute while the latter makes the quantity 0·00703 inch These results were obtained by an instrument called a *pyrheliometer*, (which see), by means of which the total amount of heat falling on a given area can be measured, and expressed in terms of a known quantity of mercury or water raised through a certain number of thermometric degrees From various determinations it has been calculated that the total amount of heat received by the earth in one year, including that absorbed by the atmosphere, would be competent to melt a stratum of ice 105 feet in thickness, surrounding the whole earth At the actual surface of the sun, ice would be melted at the rate of 2400 feet in thickness per hour The heat which we receive from the sun is not only enormously weakened by the distance, but the aqueous vapour in our atmosphere intercepts no less than four-tenths of the total quantity of heat which enters it The amount of solar heat which falls upon the earth being determined, it at once becomes possible for us to calculate the *total* amount of heat emitted by the sun. Let us imagine that the sun is the centre of a hollow sphere, the radius

of which is the distance of the earth from the sun, now the area of the sphere can be calculated, as also the area of the section of the earth, which intercepts all the heat falling upon it The relation of these areas to each other is as 1 2,306,000,000, therefore, the earth receives only $\frac{1}{2,300\,000\,000}$ of the total amount of heat emitted by the sun Various theories have been propounded in order to account for the source of the sun's heat, and its maintenance The sun dissipates in one year as much heat as would be produced by the combustion of a stratum of coal seventeen miles in thickness surrounding the sun, and we have no reason to imagine that either a greater or less amount of heat is given out now by the sun than in former ages We cannot imagine that the sun is a molten globe in process of cooling, for it would long since have dissipated its surface heat, nor can we believe that combustion is taking place at the surface of the sun, for the supply of combustible matter, and of gases to support the combustion, could by no possibility be maintained Indeed, if the sun were entirely composed of coal, and supplied with oxygen sufficient to consume it, it would be burnt up in the course of five thousand years A bold and ingenious theory of the source of the heat of the sun has been elaborated by Mr Waterston (*British Association Reports*, 1853)—the so-called *Meteoric Theory of the Sun's Heat* According to this the heat is supplied and maintained by mechanical means, by the conversion of the motion of masses of matter into heat We have before seen (see *Heat*), that mechanical force and heat are convertible, and Mr Waterston conceives that there is a constant rain of meteorites on the sun's surface The velocity of meteors near the sun is prodigious, it may amount to 300 or 400 miles per second, and their force of impact, and the resulting heat, would be also prodigious

2 *Heat of the Moon* Many attempts have been made to measure the heat of the moon, there is a general feeling that heat must accompany light, and some of the older observers thought they could detect the heat of the moon by means of an ordinary thermometer Tchirnhausen condensed the beams of the moon by means of his large burning-glass, but could get no indication of heat, and a few years later La Hire condensed moonlight more than 300 times with the same result After the invention of the thermo-electric pile (the most delicate detector of heat with which we are acquainted), Melloni and Forbes made certain experiments, in which moonlight was powerfully condensed on this instrument, but without any very definite results Forbes calculated that if the moon did transmit any heat at all, its heating effect when at the full at the surface of the earth was less than $\frac{1}{200\,000}$ part of a degree centigrade We have stated above that our atmosphere absorbs four-fifths of the heat which enters it, now it was imagined by Professor Piazzi Smith that although at the surface of the earth the heat of the moon could not be detected, it might be apparent at a great altitude above the earth, where less heat would have been absorbed, accordingly, in 1856, he tried the effect of the moon upon a thermopile at an elevation of 10,000 feet, at which he had established an astronomical station for various experiments There was no doubt now that heat accompanies moonlight, and Smyth estimated the heat as equal to that emitted by the hand at a distance of 3 feet M Marié-Davy has estimated this as 750 millionths of a degree centigrade Lord Rosse has recently made fresh experiments on the heat of the moon, using for that purpose a 3-feet reflecting telescope, and a very sensitive thermopile His experiments have led him to the conclusion that the heating effect of the moon upon the earth is $\frac{1}{80\,000}$ that of the sun, and he concludes that the surface of the moon possesses a temperature of about 500° F (*Proc Royal Society*, vol xvii, p 436)

3 *Heat of the Stars* In February 1869 Mr Huggins communicated a "Note on the Heat of the Stars" to the Royal Society, in which he mentions that in the summer of 1866 he was led to imagine that the heat of the stars might possibly be detected more easily than the solar heat reflected from the moon, and that he shortly afterwards obtained decisive evidence of stellar heat in the case of the stars Sirius, Pollux, and Regulus He employed a refracting telescope of 8 inches aperture to concentrate the heat, and a very sensitive thermo electric pile to indicate it Pollux indicated the least amount of heat, then Sirius, Regulus, and Arcturus in a slightly increasing amount, while Castor showed none at all On January 13th, 1870, a paper on "Approximate Determinations of the Heating Powers of Arcturus and α Lyræ," by Mr E J Stone, was read before the Royal Society, and it possesses matter of much interest, as the author endeavoured not only to detect stellar heat, but also to measure its intensity by the most delicate and refined means at the command of physicists The details of the determinations are somewhat complex, and we will content ourselves with giving Mr Stone's concluding remarks —"From the whole of these observations, I think we may conclude that Arcturus gives to us considerably more heat than α Lyræ, that the amount of heat is diminished very rapidly as the amount of moisture in the air increases, that nearly the whole heat is intercepted by the slightest cloud, that as first approximations, the heat from Arcturus, at an altitude of 25° at Greenwich, is about equal to that from a 3-inch cube containing boiling water, at a distance of 400 yards.

The heat from *a* Lyræ, at an altitude of 60°, is about equal to that from the same cube at a distance of about 600 yards."

4. *Production of Heat by Mechanical Means.* Passing now from the extra-terrestrial sources of heat, we arrive at the causes of its generation on the surface of the earth. Whenever matter in motion is retarded by friction or by other means, or stopped by collision, the motion is resolved into heat, as described in the account of the determination of the mechanical equivalent of heat. In physics, the term *energy* (ενεργεια, action, operation), is employed to designate the power of doing work against, or overcoming the action of, any force. Energy exists in two forms, viz., as *Potential Energy*, or possible energy, and as *Dynamic Energy*, or actual energy, and the former is perpetually passing into the latter, and this into heat. Potential energy is also called possible energy, or energy of position, or energy of tension; it is energy existing in possibility not in act, as in the case of a mass of matter suspended above the earth's surface, or an arrow resting on a tense bowstring; the mass can fall under the action of gravity so soon as it is released, and the arrow can fly upwards under the action of the tense bowstring so soon as it is released. Dynamic energy (δυναμις, power), is also called energy of motion, or kinetic energy (κινησις, motion), and *vis viva*, and mechanical energy; it is the actual energy of a body in motion, as when a mass falls to the earth, or an arrow is projected from a released bowstring. Heat which results from mechanical means arises from the conversion of possible energy into actual energy, and of this latter—the motion of a mass—into the peculiar motion of molecules of matter called heat. Friction, percussion, compression, and the partial or complete stoppage of motion in any form, and by any means whatsoever, afford examples of the production of heat by mechanical means. The relationship between dynamic energy and heat is measured in foot-pounds, and established in the form of the "mechanical equivalent of heat" (which see), forms the basis of the mechanical theory of heat. Friction has been used from the very earliest times for the production of fire, and is still employed by savages. Lucretius mentions that fire was first made known to mankind, either by clouds meeting violently in collision, and dashing out sparks of fire like flint and steel, or by the friction of the branches of trees during high winds. The flint and steel, and indeed our modern matches, afford examples of the production of heat by friction, but the many experiments which illustrate this are too well known to need description. A metal button may be rubbed till it is too hot to touch; a gimlet and saw are sufficiently hot to melt beeswax, or to ignite phosphorus immediately after use. Heat also results from fluid friction, as shown in Joule's determination of the mechanical equivalent of heat. If water be simply shaken in a bottle (great care being taken to surround the bottle with thick flannel, to prevent any communication of heat from the hand), the temperature may be raised in less than a minute from 0·7° F. to 0·8° F., while in the case of mercury, a rise of 1·3° to 1·5° F. may be produced. A locked wheel sometimes has its bearing surface raised to a red heat by the friction, and when the brake is suddenly applied to a railway van, a copious train of sparks may be noticed in the rear of the wheel. Percussion also produces heat; if a weight is raised to a height above the earth's surface and then released, it falls and comes into collision with the earth, and is then found to be hotter than before; its possible energy has become actual energy, its actual energy has become heat. Again, a nail may be hammered until, in less than two minutes, it is brought to a bright red heat. When a pistol is cocked, potential energy is conferred upon the hammer, and it is comparable to a raised weight; when the trigger is pulled the potential energy becomes kinetic; when the hammer strikes the cap, the kinetic energy becomes heat, equal to that expended in raising the hammer. Compression produces heat; a piece of wood compressed in a hydraulic press is warmer than before; and during the rolling of metals at the Mint, the bar, after compression, is so hot that water boils upon its surface. By causing a conductor to revolve between the poles of a powerful electro-magnet, Joule proved a considerable development of heat thus resulting from the friction of a metal against the magnetised ethereal medium. These varied actions are so many examples of the production of heat by mechanical means, or, more strictly, of the conversion of the visible motion of a mass into the motion of invisible molecules of matter called heat.

5. *Production of Heat by Chemical Action.* Combustion is the union of substances, under the influence of the attractive force called chemical affinity, attended by the evolution of light and heat, as when antimony is brought into contact with chlorine, or when carbon combines with oxygen to form carbonic acid gas. Combustion is the means by which we obtain all artificial heat for the general purposes of life, and the form of combustion we employ is the union of carbon, contained in charcoal, coal, wood, and our various fuels, with the oxygen gas contained in the atmosphere. By what precise means these chemical actions give rise to the production of heat we do not know, but it is believed that the molecules of two substances about to combine are in the condition of a raised weight and the earth, and when they rush together to combine, their kinetic energy becomes heat, as in the case of the weight mentioned above.

6 *Production of Heat by Electricity* The heating effects of lightning are considerable, houses are set on fire, metal rods are melted, and sand is vitrefied by its means On a smaller scale, metallic wires may be dissipated in vapour by the discharge of a powerful battery If we employ Voltaic electricity, and cause the current to pass along a very thin wire, it experiences resistance, and the wire may be raised to a white heat, and ultimately fused We do not at present know the cause of the production of heat by electricity, possibly, in the experiment last mentioned, the electricity in passing along the thin conduction wire may so agitate its molecules that they collide, and heat results, or, in other words, the electricity may indirectly confer kinetic energy upon the molecules of the conduction wire, which energy is ultimately resolved into heat

7 *Intra Terrestrial Heat* The heating power of the sun does not extend to a greater depth than 85 feet in our latitudes, while it is greater at the equator, and less at the poles At a certain depth there is a layer of constant temperature, and below this the temperature increases about 1° F for a descent of 60 or 70 feet, at a depth of about 30 miles, if this increase is regular, the heat would be sufficient to fuse the most refractory granites and basalts We have good evidence of an intense source of heat within our globe, in the molten lava which is ejected from volcanoes, but no satisfactory hypothesis has been adduced to show the cause of this central heat Its effect on the surface of the earth is very insignificant, for it does not raise the temperature more than $\frac{1}{30}$th of a degree

HEAT SPECTRUM In a beam of sunlight there are not only luminous rays, but also invisible heat rays, and the latter are capable of being refracted when passed through certain media in precisely the same manner as the luminous rays which accompany them Hence, when a beam of light is decomposed by means of a prism, we obtain not only a light spectrum, but also an invisible heat spectrum The Abbé Rochon endeavoured to determine the comparative heating powers of the various coloured rays of the spectrum, in 1776, he employed for this purpose a flint glass prism and an air thermometer, and he estimated the heating power of the red rays to be about eight times as great as that of the violet rays In 1798, Leslie, by means of a differential air thermometer, found the relative heating powers of the blue, green, yellow, and red rays, to be as 1 4 9 16 In 1800, Sir W Herschel employed a small mercurial thermometer for the same purpose, and arrived at the conclusion that the hottest part of the spectrum is beyond the red rays Professor Muller, of Freiburg, afterwards examined the solar spectrum by more accurate means, and mapped the heat spectrum, the distribution and intensity of the heat being represented by means of a curve, as suggested by Sir William Herschel. Professor Tyndall has recently measured and mapped the heat spectrum of the electric light with great accuracy, and it may be well for us to consider the means which he employed The electric light apparatus was fitted with Foucault's regulator, and in the orifice of the lantern a lens of rock salt was placed so as to render the rays which issued from the voltaic arc perfectly parallel A lens of rock salt was employed in place of the ordinary glass lens, because rock salt cuts off a far less amount of heat than glass The parallel beam passed through a narrow slit, and then through a second rock salt lens, behind this lens there was a prism of rock salt, by means of which a spectrum was cast upon a screen A very delicate thermo-electric pile, having a vertical linear opening 0·03 inch wide, was used to measure the heat at various points of the spectrum Now if the maximum intensity of heat be called 100, Tyndall found the intensity in the blue portion of the visible spectrum to be 0, there was actually no sensible heat, even when tested by so delicate an instrument, on entering the green it was 2, on entering the red the intensity rose at once to 21, and at the extreme red, that is, the extreme limit of the visible spectrum, it was 45 The intensity now increased rapidly to 100, and then passed rather quickly to 2 It was thus found that the length of the heat spectrum considerably exceeds that of the entire visible spectrum from violet to red, and when the intensity was measured by means of a curve, the latter was found to commence in the blue, and to ascend gradually until just beyond the red it "shoots suddenly upwards in a steep and massive peak—a kind of Matterhorn of heat—which quite dwarfs by its magnitude the portion of the diagram representing the visible radiation" In the case of the heat spectrum obtained from a beam of sunlight this curve is less steep, because the aqueous vapour in the atmosphere absorbs a considerable amount of the obscure heat rays In fact while the invisible radiation of the sun's light as it reaches us is only about double that of the visible, the invisible radiation of the electric light is nearly eight times greater than the visible, because the rays pass through an infinitely thinner layer of aqueous vapour than those from the sun The account of the complete separation of the invisible heat rays from the visible light rays of the electric light, will be found under the heading *Calorescence* (See also *Obscure Heat*, *Radiant Heat*)

HEAVY GLASS See *Silicates*, *Silicate of Lead*.

HEAVY SPAR. See *Sulphates*, *Barium*

HELIACAL (ἡλιακός, belonging to the sun.) The ancient astronomers spoke of a star as rising *heliacally*, when it rose just so long before the sun as to be visible in the morning twilight A star was said to set *heliacally* when it set just long enough after the sun to be visible in the evening twilight (See *Acronycal* and *Cosmical*)

HELIOCENTRIC (ἥλιος, the sun, κέντρον, centre) A term used in astronomy to express the position or motions of the members of the solar system with respect to the sun's centre The *heliocentric longitude* of a planet is the angle included between two planes through the sun's centre, and at right angles to the plane of the ecliptic, one passing through the first point of Aries, the other through the planet's centre It is measured from the first plane to the second in the order of the signs, and so may have any value between 0° and 360° The *heliocentric latitude* of a planet is the angle which a line joining the centres of the sun and planet makes with the plane of the ecliptic, and is called north or south according as the planet is north or south of the ecliptic

HELIOSTAT (ἥλιος the sun, and στατος, stand) A reflecting mirror mounted equatorially, and driven by clockwork at such a rate that the apparent diurnal motion of the sun is neutralised When properly adjusted a beam of sunlight reflected from it may be kept steadily in one direction all day

HEMMING'S JET A safety jet sometimes used for the explosive gases employed for the *Lime Light* It consists of a tube tightly packed with fine wires, through which the mixed gases have to pass on their way to the jet The flame will not pass along the fine interstices left between the wires, and, therefore, if the pressure is deficient, and the flame blows back it will be extinguished before it gets to the reservoir of mixed gases. (See *Lime Light*)

HERAPATHITE See *Iodoquinine*

HERCULES One of Ptolemy's northern constellations This constellation includes within its limits the point towards which the sun is travelling The magnificent star cluster, 13 Messier, belongs to this constellation It is situated between the stars Eta and Zeta Other remarkable clusters and nebulæ are to be found in this fine constellation

HERSCHEL A name given by continental astronomers to the planet Uranus

HERSCHELIAN TELESCOPE A form of reflecting telescope made by Sir William Herschel. It is the simplest of all, having only one speculum The rays from the object fall on the speculum, which is placed rather sloping in the tube, and, therefore, converges them to a focus at the side of the tube, where they are received direct into the eyepiece The 40 foot reflector was of this construction

HIPPURIC ACID One of the normal constituents of urine, it is increased by vegetable food, and occurs in comparatively large quantity in the urine of the horse, hence its name, from ἵππος, a horse Formula $C_9H_9NO_3$ It is easily converted into benzoic acid by oxidation, and is largely used as a source of this acid, it forms colourless transparent prisms, sparingly soluble in cold water, but readily soluble in boiling water and alcohol. (See *Animal Nutrition*)

HOAR-FROST Frozen dew (See *Dew*)

HOMAN (Arabic) The star ζ of the constellation Pegasus

HOMOGENEOUS LIGHT Light of one degree of refrangibility, consequently of one colour The light from incandescent vapours of lithium, sodium, and thallium are homogeneous, being respectively red, yellow, and green Such light passing through a prism is refracted only, but not dispersed.

HOMOLOGOUS SUBSTANCES In organic chemistry, substances are called homologous which differ from one another in composition by CH_2 or any multiple thereof, thus the alcohol series, the fatty acid series, and the aromatic series are composed respectively of homologous bodies (See *Alcohols*) Fatty acids, aromatic acids, and homologous bodies generally exhibit a regular gradation of physical and chemical properties

HORIZON. (ὁρίζω, to bound) In astronomy the plane of a great circle of the sphere dividing the visible from the invisible portion The term is applied to two different circles. One is called the *sensible horizon*, and is definable as the circle in which the tangent plane to the earth, at the place occupied by the observer, meets the celestial sphere. The other, called the *rational horizon*, is the circle in which a plane through the earth's centre parallel to the sensible horizon meets the celestial sphere With respect to all the celestial objects, except the moon, the two circles may be regarded as practically coincident

HORIZONTAL PARALLAX See *Parallax*.

HOROLOGIUM (The Clock) One of Lacaille's southern constellations

HORN SILVER. The mineralogical name for chloride of silver. (See *Silver*)

HORN STONE See *Quartz*

HORSE-POWER. The term horse-power, applied as a measure of the mechanical effect of

steam-engines and other machines, has no reference to the actual work of the horse, which is of of necessity very variable. When the work of a machine is equal to 33,000 foot pounds per minute, it is said to be of one horse-power. A machine of 50 horse-power means a machine capable of producing in one minute a mechanical effect equal to 50 × 33,000 foot-pounds. (See *Foot Pound*.)

HOROLOGY (ὥρα, time, and λόγος, discourse). The science which treats of methods of measuring and marking the hours of the day. The term horology was formerly applied to any contrivance for measuring time, as the clepsydra and sun-dial. Horology now embraces the principles of the construction of clocks and watches. The date of the introduction of a combination of wheels and pinions to measure time is uncertain, but it is known that in 1364 a German named Henry de Wyck set up a clock, regulated by a balance, for Charles V of France. Since this date clocks and watches have superseded all other contrivances for marking the hours of the day. All varieties of time pieces include five essential parts.

1. A moving power.
2. An indicator by whose uniform motion time is measured.
3. An accurately divided scale over which the indicator moves.
4. A certain mechanism by which motion, originating with the moving power, is imparted to the indicator.
5. A regulator to render the motion of all the parts uniform.

In the common clock the moving power is a weight suspended by cords over a pulley, which it causes to revolve. The indicator is the hand, and the scale is the dial plate. The mechanism is a combination of toothed wheels and pinions, so arranged as to secure a required relation between the times of revolution of the first wheel and the last. The regulator of a common clock consists of a pendulum and escapement wheel. (See *Pendulum* and *Escapement*.) The former oscillates regularly in equal times, and allows one tooth of the escapement wheel to pass it at each oscillation. The escapement is connected with the train of wheels moved by the weight, and therefore regulates their motion and renders it uniform. Hence the regulating power of the pendulum depends on the following facts:—

1. The time of oscillation is always the same for the same pendulum.

2. This time may be made shorter or longer by varying the length of the pendulum, a pendulum oscillating in one second being 39 inches long, one oscillating four times a second being half his length, nine times a second a third of this length, and so on.

3. The motion of the pendulum can be made to regulate the revolution of the escapement wheel. The teeth of the escapement wheel are so constructed as to exert a lateral pressure on the pendulum during one part of its motion, so as to repair the loss of momentum in the pendulum arising from friction and resistance of the air.

For watches and time pieces in which the space required for the ascent and descent of the weight would be inconvenient, the moving power is the elastic force of a main spring. It is a ribbon of highly-tempered steel, bent in the form of a spiral. When the spring is coiled round its axle or arbor it has a tendency to uncoil itself. The arbor is free to revolve, and is therefore set in motion by the spring. The force of the spring is a variable power, and sure means is therefore required to render its effect regular and uniform. This is accomplished by a beautiful contrivance termed the fusee, a conical barrel surrounded by a flexible chain. (See *Fusee*.) The regulating part of a watch is usually the balance-wheel. It consists of a fly wheel, having a heavy rim and a fine spring, termed a *hair spring*, attached by one extremity to the axle of the wheel, and by the other to a fixed point. The spring is placed in a certain spiral form natural to it, and to which when disturbed it has a tendency to return. When the wheel is drawn aside, therefore, the spring causes it to oscillate. The oscillations of the spring, like those of a pendulum, are isochronous. An escapement wheel renders the balance-wheel effective in regulating the motion of the other parts.

In the machinery of the watch or clock it is necessary to interpose a series of wheels between the main-spring and balance-wheel, so that the main spring by acting through a small space may produce the required number of revolutions of the escapement wheel. Without this number the spring would require frequent winding up. The same applies to the work of a clock.

The following works may be referred to on the subject:—Reid's *Treatise on Clock and Watch Making*, Derham's *Artificial Clockmaker*, Denison's *Rudimentary Treatise on Clocks*, Earnshaw's *Explanations of Timekeepers*, Berthoud, *Essai sur l'Horlogerie*, and *Histoire de la Mèsure du Tems*.

HOT-AIR ENGINE. The fact that air expands considerably when heated has frequently suggested its use as a motive power instead of steam, and several very useful engines have been constructed to work by the expansion of heated air. Dr Joule proposed various engines which

in theory (that is to say, supposing no loss of force to arise from friction or radiation), would leave as much as half the heat of combustion available for work, that is, about five times the fraction which has been attained in the most perfect steam engine Mr Stirling was the first to construct a working hot-air engine One of the simplest forms of air engine consists of a receiver into which air is compressed by a pump, and in which it is afterwards heated, and a cylinder communicating with the receiver, the piston of which is worked by the air after it has been heated The available work is that expended in moving the piston less that spent in working the pump (See Phil Trans 1852, part 1) Mr Ericsson, a Swede, has considerably improved upon Mr Stirling's model Ericsson's caloric engines of sixty horse power have been constructed in America The following is a detailed description of one The cylinders are arranged in pairs, being either two or four in number The upper cylinder of each pair, which is much the smaller, is vertically over the lower, and the pistons of the two cylinders are connected, so that when the larger is made to ascend it lifts the smaller Hot air has access to the lower or *working* cylinder below the piston, and cold air to the upper or *supply* cylinder above the piston, the supplies being regulated by means of valves Let us suppose the pistons to be in their highest positions, then the lower cylinder will be filled with hot air The valves closing these cylinders are now opened, the pistons fall in consequence of their own weight, the hot air is driven out of the lower cylinder, and cold air allowed to pass into the upper cylinder When hot air is again admitted into the lower cylinder the pistons ascend, and as the valves at the top of the upper cylinder are now closed, the cold air cannot return, but is forced into a receiver From this vessel it passes to the lower cylinder, going through what is called the *regenerator* in its passage The regenerator is a vessel to which heat is applied on the side remote from the receiver and nearest the cylinder Within it are placed sheets of fine wire net-work like that used for sieves, the number of sheets being sufficient to form a thickness of about 12 inches In passing through the innumerable cells formed by these reticulated sheets the air is heated to a very considerable temperature In this state it passes to the lower cylinder, under which a fire is applied, so that on entering the cylinder the air is still further heated until the small cylinder full of cold air is heated and expanded as exactly to fill the large cylinder As the pistons are unequal in area the upward pressure on the lower or larger piston exceeds the downward pressure on the upper or smaller piston, and the difference of the pressures is the working power of the engine When the hot air has done its work, it is driven again through the meshes of the regenerator, where it leaves much of the heat it received there, and then passes away from the machine

Air engines will obviously have an advantage over steam-engines where a sufficient supply of water cannot be obtained All attempts to establish them as marine engines have hitherto failed (See *Heat-Engine*)

HOUR-ANGLE The angle between the hour circle of a body and the meridian of the place of observation

HOUR CIRCLE In an equatorial telescope the graduated *position circle*, attached to the polar axis, is called the hour circle, it is graduated to degrees, and also to hours from one to twenty four, and is supplied with two verniers by which seconds can be read This circle is sometimes connected with a clock movement, by which the telescope is moved on the polar axis (See *Telescope*, *Equatorial*, *Position Circle*)

HOUR-CIRCLE In astronomy a circle on the heavens, passing through the position of a celestial object, and the poles of the heavens

HUMIC ACID, or, *Ulmic Acid* A brownish black substance occurring in vegetable mould and liquids containing decomposing vegetable substances It may be produced by boiling sugar for some time with a dilute mineral acid, when black or brown scales are deposited, these are washed in water and digested with ammonia A black insoluble substance called Ulmin is left behind, and the solution, on being neutralised with an acid, deposits humic acid in brown or black flocks The composition of humic acid is $C_{24}H_{18}O_9$, it is soluble in pure water, but insoluble in dilute acids, or some neutral salts

HUMIDITY (*Humidus*, moist) A term used by meteorologists in speaking of the amount of moisture present in the air It is used in two senses *Absolute humidity* refers to the actual amount of aqueous vapour present in the air, *relative humidity* refers to the proportion between the amount of aqueous vapour actually present in the air, and the quantity which the air could, at its actual temperature, retain in the invisible state (See *Saturation*) The latter usage corresponds with the ordinary use of the term humidity or dampness as applied to the air, since the effect which we ordinarily term dampness depends, not on the actual amount of vapour present in the air, but on the circumstance that the air is nearly saturated.

HUNTER'S SCREW See *Differential Screw, Hunter's*

HURRICANE. See *Winds*, *Cyclone*.

HUYGHENS' EYE-PIECE. See *Negative Eye Piece*.

HYACINTH. See *Zirconium*.

HYADES (Ὑάδες, the rain.) In astronomy a group of stars near, and including Aldebaran, and connected with the Pleiades by a well marked stream of stars.

HYALOID MEMBRANE (ὕαλος, glass.) A transparent membrane in the convoluted folds of which the vitreous humour is contained. (See *Eye*.)

HYDRA (The Water Serpent.) One of Ptolemy's southern constellations, remarkable for its great extension. It has been proposed that this constellation should be divided into portions of more convenient dimensions, but hitherto no successful attempt has been made to effect this. The constellations Corvus and Crater were originally regarded as subdivisions of Hydra, and named accordingly Corvus et Hydra, and Crater et Hydra. This inconvenient nomenclature has, however, been abandoned. Extending as Hydra does from the neighbourhood of Cancer to that of Libra, that is along four signs of the Zodiac, it is clear that any arrangement by which its preposterous length should be diminished would be a decided improvement.

HYDRATE OF CHLORAL. See *Chloral*.

HYDRATES. Terms applied to compounds containing water, or its elements in the proportion to form water, thus $Na_2O\,H_2O$ is called hydrate of sodium. $SO_3\,H_2O$ is hydrated sulphuric acid. $Fe_4H_6O_6$ is hydrated ferric oxide. C_2H_6O is common alcohol, or hydrate of ethyl. Hydrated salts are those which contain water of hydration or crystallisation, thus $ZnSO_4\,H_2O + 6\,aq$ is hydrated sulphate of zinc, the six molecules of water are held with less tenacity than the other atom.

HYDRAULIC RAM. See *Water Ram*.

HYDRAULICS. See *Hydro-dynamics*.

HYDRAULIC PRESS, or, *Bramah's Press*. It follows from the principle of the distribution of pressure through liquids (see *Pressure through Liquids*), that if a vessel be completely filled with water and have two tubes of equal diameter fitted into it at any two places, which tubes are also completely full of water, and fitted with pistons, any inward pressure applied to the one piston, will give rise to an equal and outward pressure on the second piston. If, instead of the second tube, there be two equal ones, side by side, each of them will be pressed outward by the same force. Hence, if the piston rods of the two neighbouring tubes be connected together, the two together will be pushed outwards with a force equal to twice the force with which the first is pushed in. Further, if instead of having the two cylinders side by side, they are joined together so as to make one cylinder of twice the sectional area, the larger piston will be pressed outwards with a force equal to twice the force applied to press the first piston inwards. If the first piston have a sectional area of 1 square inch, and be pressed inwards with a force of 1 pound, the second piston will, if it have a sectional area of 3 square inches be pressed outwards with a force of 3 pounds, and so on. In short, the pressure on the two pistons, supposing them to keep one another in equilibrium will be directly proportional to the superficial area of the pistons or sectional area of the cylinders. If, therefore, one cylinder (and piston) be exceedingly narrow in comparison with the other cylinder (and piston) there will be a corresponding disproportion between the forces which, when applied to the respective pistons will keep one another in equilibrium. It follows, of course, from the principle of the conservation of work, or indeed directly from the constancy of the quantity of water that the paths moved through by the narrow and wide pistons are inversely proportional to their superficial area, that is, inversely proportional to the forces themselves. The hydraulic press (called also from its inventor, Bramah's Press) depends upon the above principle. It consists essentially of an exceedingly strong capacious iron cylinder, through the top of which works, water tight, a large solid cylindrical piston or "plunger," which, when at its lowest, nearly fills the cylinder. A narrow tube communicates, on the one hand, through the side of the first cylinder, with its cavity; on the other, with a very much smaller strong cylinder, also provided with a plunger piston. The bottom of the small cylinder communicates with a reservoir of water or oil. In the tube connecting the two cylinders, there is a valve which opens towards the larger one. In the tube connecting the lesser cylinder with the reservoir of liquid, there is a valve which opens towards the lesser cylinder (upwards). The plunger of the little cylinder is worked up and down by a lever or fly-wheel, acting on the plunger by a mechanism of "parallel motion." When the plunger of the little cylinder is forced down, the valve in the tube leading to the reservoir is forced shut; the liquid is forced along the connecting tube into the greater cylinder and lifts its plunger. When the little plunger is lifted, the liquid cannot return from the larger cylinder, on account of the valve in the connecting tube, but the liquid rises from the reservoir through the valve into the little cylinder, being pushed by the atmosphere to which its surface is exposed. At every down stroke, therefore, there is forced into the larger cylinder a quantity of liquid equal to the volume of the lesser plunger which is thrust

into the little cylinder. Since the liquid is practically incompressible, the larger plunger is thrust out to make room for this volume of liquid. As its sectional area is very large, it need only move a little way for this purpose. In short, if the sectional area of the larger plunger be 1000 times as great as that of the smaller, a force of 1 lb on the smaller plunger will, neglecting friction, lift a force of anything under 1000 lbs in the larger one. The hydraulic press is much used where immense pressure has to be applied through short ranges of distance. The range is, of course, for one position of the machine, limited to the length of the larger plunger and cylinder. This press is useful for expressing oil from seed; testing steam boilers; starting a ship which is to be launched; compressing cotton for importation. When a longer range of force is required, as in lifting girders of bridges, &c, the weight must, of course, be supported after being lifted, until the press itself is raised bodily to a higher level. So great, in some instances, is the pressure which has been obtained in the hydraulic press that the water in the larger cylinder has been forced through its sides,—a thickness of more than six inches of wrought iron.

HYDRIDES, PRIMARY, OXIDES OF. According to Dr Odling:—

Formula	Oxhydrate, &c	Derivatives.	
	Monobasic		
HCl	Chlorhydric	KCl	$EtCl$
$HClO$	Hypochlorous	$KClO$	—
$HClO_2$	Chlorous	$KClO_2$	—
$HClO_3$	Chloric	$KClO_3$	—
$HClO_4$	Perchloric	$KClO_4$	$EtClO_4$
	Dibasic		
H_2S	Sulphydric	KHS	Et_2S
H_2SO	—	Cl_2SO	Et_2SeO
H_2SO_2	—	Cl_2SO_2	—
H_2SO_3	Sulphurous	$KHSO_3$	Et_2SO_3
H_2SO_4	Sulphuric	K_2SO_4	$EtHSO_4$
	Tribasic		
H_3P	Phosphine	Ag_3P	Et_3P
H_3PO	—	Cl_3PO	Et_3PO
H_3PO_2	Hyphosphorous	KH_2PO_2	—
H_3PO_3	Phosphorous	K_2HPO_3	Et_3PO_3
H_3PO_4	Phosphoric	K_3PO_4	EtH_2PO_4
	Tetrabasic		
H_4Si	Silic Hydrogen	$Mg_2''Si$	Et_4Si
H_4SiO	—	—	—
H_4SiO_2	—	—	—
H_4SiO_3	—	—	—
H_4SiO_4	Silicic acid	K_4SiO_4	Et_4SiO_4

HYDRIODIC ACID. A colourless gas composed of equal volumes of hydrogen and iodine vapour. Formula HI. Specific gravity 4.435. It is rapidly absorbed by water, forming an aqueous solution, which fumes strongly in the air, and possesses powerful acid properties. On exposure to the air it decomposes with absorption of oxygen and separation of free iodine. In its chemical properties it is somewhat similar to hydrochloric acid.

HYDROBROMIC ACID. A gaseous compound of bromine and hydrogen, composed of equal volumes of bromine vapour and hydrogen. It is a colourless strongly acid gas, having a pungent odour. Formula HBr. Specific gravity, 2.8. It is greedily absorbed by water, forming a strongly acid solution which fumes in the air. The properties of this acid are very similar to those of hydrochloric acid.

HYDROCARBONS. Combinations of hydrogen and carbon. These form a very important and numerous class of organic bodies. Their number is considerable, and fresh members are being constantly discovered. They may be divided into groups, of which the following are the most important:—

Alcohol radicals, of which	Methyl $(CH_3)_2$, may be taken as the type.
Hydrides of alcohol radicals,	Marsh Gas, CH_4, " "
Olefines, "	Olefiant Gas, C_2H_4 " "

Hydrocarbons, of which	Acetylen C_2H_2,	may be taken as the type	
Camphenes,	„ Turpentin, $C_{10}H_{16}$	„	„
Hydrocarbons,	„ Benzol, C_6H_6	„	„
Hydrocarbons,	„ Naphthalin, $C_{10}H_8$	„	„

The lower members of the first four of the above groups are gaseous, whilst the highest members of all are solid The great majority of hydrocarbons are, however, gaseous The most plentiful source of hydrocarbons is the destructive distillation of wood, coal, and similar bodies

HYDROCHLORIC ACID. A gaseous compound of chlorine and hydrogen, formed by mixing the two gases in equal volumes They do not unite in total darkness, but a lighted match or exposure to the sun's rays causes them to explode, whilst diffused daylight or faint artificial light induces their slow union They unite without contraction or expansion Hydrochloric acid is usually prepared by decomposing chloride of sodium by strong sulphuric acid. In the dry state hydrochloric acid is a colourless, strongly acid gas, having a pungent odour Formula HCl Specific gravity, 1 27 Water dissolves 458 times its volume of the gas, forming the ordinary hydrochloric acid of commerce The gas liquifies at a pressure of 40 atmospheres, it is not inflammable, and extinguishes ordinary burning bodies, although potassium burns in it, forming chloride of potassium A strong solution of hydrochloric acid when pure is colourless, its specific gravity is 1 21, and it fumes copiously in the air, it boils at a little above the ordinary temperature, evolving hydrochloric acid gas, and when the temperature rises to about 100° C (212° F) a solution of the acid comes over containing one molecule of HCl dissolved in 8 molecules of water Hydrochloric acid possesses strong solvent powers on many metals, hydrogen being evolved, and metallic chlorides being produced, it reddens litmus and has an intensely sour taste Mixed with nitric acid it forms nitro hydrochloric acid or *aqua regia*

At the Liverpool meeting of the British Association, held in September 1870, Mr Henry Deacon illustrated a very simple method of decomposing hydrochloric acid, and getting the chlorine from it in an available form He passes a mixture of hydrochloric acid and air at a temperature of about 700°–750° F through tubes containing pieces of brick soaked in solution of sulphate of copper and dried The sulphate of copper remains unchanged, and appears capable of converting an indefinitely large quantity of hydrochloric acid and atmospheric oxygen into chlorine and aqueous vapour This process succeeds well, as a laboratory experiment, and is about to be employed on a manufacturing scale for making bleaching powder (chloride of lime)

HYDRO-DYNAMICS This branch of physics considers the motion of liquids The application of liquid motion to machinery, and the application of mechanical force to procure required motion in liquids form the subject of *Hydraulics*

HYDRO ELECTRIC MACHINE See *Electric Machine*

HYDRO FLUORIC ACID A compound of fluorine and hydrogen, analogous to hydrochloric, hydrobromic, and hydriodic acids, it has recently been submitted to detailed examination by Mr Gore (*Phil Trans* 1869, p 173) In the anhydrous state it is a perfectly colourless transparent liquid, very thin and mobile, specific gravity 0 9879, boiling at 67° F, densely fuming in the air at ordinary temperatures, and absorbing water very greedily from the atmosphere. It does not corrode glass in the slightest degree In physical and chemical properties it appears to lie between hydrochloric acid and water Aqueous hydrofluoric acid attacks glass and rock crystal with violence They are both highly dangerous substances, and require extreme care in their manipulation The composition of the anhydrous acid is expressed by the symbols HF. It dissolves most of the metals, forming *Fluorides*

HYDROGEN. A colourless inodorous gas, the lightest known substance, being 14½ times lighter than atmospheric air Specific gravity, 0 0693 It is very inflammable, burning in the air with an almost colourless flame and uniting with the oxygen to form water Its exceeding lightness renders it possible to transfer hydrogen from one vessel to another by a process of pouring with the vessels held upside down, it may also be collected by displacement in a vessel held mouth downwards, and it is occasionally used for filling balloons The atomic weight of hydrogen is 1, and its symbol H It is usually prepared by dissolving zinc, in dilute sulphuric acid when the metal takes the place of the hydrogen which is evolved It is also frequently prepared at lectures by introducing a piece of sodium into an inverted cylinder filled with water standing in a pneumatic trough, the sodium removes the oxygen from the water, and liberates the hydrogen Hydrogen is never met with free in nature, but it forms one ninth part of water, and is a constant constituent of organic bodies A mixture of two parts by bulk of hydrogen with one of oxygen forms a violently explosive compound, the two uniting on contact with flame, without any residue, to form water If the vessel is not very strong, it is shattered to pieces, but if of sufficient strength to resist the explosion, no noise is

heard A similar detonation, but less violent, is produced when hydrogen is mixed with two and a half times its volume of atmospheric air and ignited Combination of the explosive mixture is also effected at the common temperature by contact with a plate of platinum or a piece of platinum sponge, in the latter case the temperature rapidly rises to the igniting point When the mixed gases are forced from a fine jet and ignited, they constitute the oxyhydrogen blow pipe (see *Blow-pipe, Oxyhydrogen*) which is one of the highest artificial sources of heat Hydrogen unites with oxygen in two proportions, forming the protoxide, *water* (H_2O) and the *peroxide* (H_2O_2) The properties of water will be described under its heading Peroxide of hydrogen is a colourless transparent liquid, of specific gravity 1 452, less volatile than water, and having a harsh bitter taste, its oxidising properties are very great, the second atom of oxygen being liberated readily A rise of temperature decomposes it rapidly, sometimes even with explosive violence When placed on the skin it whitens the cuticle, and when added to various metallic solutions it quickly raises the metal to the highest state of oxidation Some substances, such as oxide of silver, peroxide of manganese, &c, added to peroxide of hydrogen, decompose it, and not only cause the extra atom of oxygen to be evolved but at the same time give up some of their own oxygen, the peroxide of hydrogen acting in this case as a reducing agent These decompositions have been examined by Sir Benjamin Brodie (*Phil Trans*, 1850, p 759), who has explained them on the supposition that the oxygen in the two bodies is contained in different states of polarity, so that when they meet they unite and are evolved together Peroxide of hydrogen is obtained by a difficult process by the decomposition of peroxide of barium with acid Amongst other compounds of hydrogen may be mentioned *antimoniuretted hydrogen, arseniuretted hydrogen, sulphuretted hydrogen, phosphuretted hydrogen, seleniuretted hydrogen, telluretted hydrogen, hydrochloric acid, hydrobromic acid, hydriodic acid, hydrofluoric acid*, besides organic compounds, which will be described under their respective headings

HYDROGENIUM From his researches on the occlusion of hydrogen by palladium, Professor Graham was led to infer the existence of an alloy of palladium, and hydrogen gas condensed to a solid form to which he gave the name of hydrogenium By an ingenious process of reasoning from the properties of this alloy of palladium and hydrogenium, the following description of the latter is deduced Its density is 0 711, it is solid, metallic, and of a white aspect, it has a certain amount of tenacity, and possesses the electrical conductivity of a metal, finally, it takes its place among magnetic metals In its alloy with palladium it decomposes chloride of mercury, unites with chlorine and iodine in the dark, reduces a persalt of iron to the state of proto-salt, and has considerable deoxidising powers not possessed by hydrogen in its ordinary condition (See *Proc R S*, 1868, p 422, 1869, pp 220, 500)

HYDROGEN LINES, BROADENING OF (See also *Hydrogen, Spectrum of*) Plucker has shown that, when the intensity of the induced current is increased, the green and blue lines seen in the hydrogen spectrum begin to broaden Lockyer has discovered that close to the sun's surface the red hydrogen line is frequently seen broadened, tapering off to its usual width in the upper regions of the chromosphere He has found this to be due to increased pressure of gas, and his observations point to the possibility of ascertaining both the temperature and pressure of the solar atmosphere at different heights above its surface (See Mr Lockyer's Paper, *Phil Trans*, 1869, p 425)

HYDROGEN, SPECTRUM OF This may be obtained either by examining the light from a hydrogen vacuum tube (see *Geissler's Tubes*) or from the terminals of a *Ruhmkorff coil* striking in hydrogen gas, in the spectroscope It consists of three bright lines—a red coincident with Fraunhofer's C, a green line coincident with Fraunhofer's F, and a blue line coincident with Fraunhofer's G Spectrum analysis has shown the presence of these luminous lines in the spectrum of the red protuberances seen during an eclipse, and Mr Lockyer and Professor Janssen have also detected them in the spectra of the protuberances and chromosphere, showing the presence of hydrogen

HYDROSTATIC ARCH See *Arch*

HYDROSTATICS Hydrostatics is the science of the equilibrium of liquids, and of other bodies (especially solids) in the maintenance of whose equilibrium liquids are concerned

HYDROSTATIC BELLOWS This toy exemplifies the law of the distribution of pressure through liquids, and also the hydraulic press (See *Pressure through Liquids*, and *Hydraulic Press*) Two circular disks of wood are joined by a folding leather, in such a manner as to form a sort of cylindrical bellows A tall narrow tube, fixed in an upright position, communicates with the interior through the lower disk On pouring water into the narrow tube, it upheaves the upper disk which may be heavily loaded If we compare this arrangement with that described under *Pressure through Liquids*, the pressure on the little piston is here replaced by the weight of the water itself in the long tube Precisely the same ratio exists between the sectional areas or surfaces of the narrow and wide tube as exists between the weight on each

Now, the weight acting down the narrow tube is the weight of the water therein, which is proportional to the height of this column

HYDRUS (The Water-Snake) One of Bayer's southern constellations It forms the prolongation of the stream of stars constituting the windings of the constellation Eridanus Half of the greater Magellanic Cloud falls within this constellation.

HYGROMETER (ὑγρος, moist, and μέτρον, measure) An instrument for determining the amount of moisture in the air is called a hygrometer There are two chief classes of hygrometers, those depending on absorption, and those depending on condensation

Substances which absorb and part with moisture readily are subject to corresponding changes of form, not obvious to the eye, but appreciable in other ways Owing to such changes of form these substances may be used to indicate the amount of moisture in the air In Saussure's hair-hygrometer, the shortening of hair when moistened is made the means of measuring the moisture of the air In Adie's *conservatory hygrometer*, two pieces of wood, of different hygrometric qualities, are glued together When the air is moist, one of these becomes longer than the other, when the air is dry, the former piece becomes the shorter Thus the compound piece curves one way when the air is dry, the opposite way when the air is moist

But hygrometers constructed on the principle of absorption, though useful for the sick room, hot house, &c, are of little scientific value

In hygrometers, constructed on the principle of condensation, the object is to determine the *dew point* (*q v*), or the temperature at which the amount of moisture actually present in the air would suffice for saturation In Daniell's and Regnault's hygrometers (the same in principle) this is done by direct experiment Daniell's consists of a glass tube bent at right angles at two points, the middle branch horizontal and uppermost, the two end branches vertical and unequal, with a bulb at the extremity of each The bulb at the end of the longer branch is partly filled with ether, in which is placed the bulb of a delicate thermometer The other bulb is covered with muslin When an observation is to be made, the muslin is wetted with a few drops of ether, evaporation follows, and the vapour of ether within the bulb condenses The pressure on the ether being thus diminished, it evaporates freely, and its temperature is thus reduced, reaching at length the dew-point, when a ring of dew begins to be formed outside the bulb The reading of the thermometer within the tube shows at this moment the dew-point In Regnault's hygrometer, air is drawn through a glass tube containing ether, and placed within a very thin, thimble-shaped silver envelope The ether is thus caused to evaporate, and the deposition of dew on the polished silver surface is easily recognised A thermometer immersed in the ether is then noted, as in the case of Daniell's hygrometer

A hygrometer in more general use, as cheaper, than either Daniell's hygrometer, or Regnault's improved form, is the *dry and wet bulb thermometer*, or *psychrometer* In this instrument two perfectly similar thermometers are placed side by side The bulb of one is covered with a piece of thin muslin, to which a few threads of darning cotton lead moisture by capillary attraction from a small vessel close by When the air is dry the moisture evaporates quickly from the muslin, the temperature is much reduced, and the wet bulb thermometer falls considerably below the other When the air is moist, evaporation proceeds slowly, and the difference between the two thermometers is thus diminished Knowing the temperature of the air and the temperature of evaporation, we can deduce the *dew point*, the *elastic force of vapour*, and the *relative humidity* The formula of reduction, and tables for assisting the process, are given in treatises on meteorology

HYPONITROUS ACID See *Nitrogen*

HYPOSULPHITE OF SODIUM A salt of hyposulphurous acid (see *Sulphur*) of considerable importance in the arts and manufactures Formula, $Na_2S_2O_3 \, 5 \, H_2O$ It forms large crystals of specific gravity 1 67, which dissolve easily in water, but the solution gradually decomposes with absorption of oxygen Acids decompose it with separation of sulphurous acid and sulphur, and chlorine has a similar action, converting it into sulphate of soda Owing to this property, it is extensively used by paper-makers and bleachers under the name of antichlore. This salt is also largely used in photography, owing to its property of dissolving chloride, bromide, and iodide of silver.

I

ICE CALORIMETER. See *Calorimetry.*

ICELAND SPAR, or, *Calcspar.* A form of carbonate of lime which is found in beautifully crystallised masses It possesses in a very high degree the property of double refraction. (See *Crystals, Double Refraction of, Polarisation of Light, Polarisation by Double Refraction*)

IGNIS FATUUS. (Foolish fire.) A luminous appearance seen over marshy places, stagnant

water, and sometimes in churchyards Its nature has never been explained Some have attributed it to an issue of marsh gas (light carburetted hydrogen), which has been accidentally ignited It seems more reasonable to conclude that it is due to some form of phosphorescence

IGNITION (*Ignis*, fire, *ignesco*, to become fire) The state of becoming luminous by the application of heat When this effect is attended with oxidation, the term *combustion* is employed. The term *spontaneous* is usually prefixed when the ignition is a consequence of slow and gradual accumulation of heat from oxidation Thus a mixture of oxygen and hydrogen gases is said to cause the spontaneous ignition of spongy platinum, which then causes the combustion of the mixture Cotton waste soaked in oil is frequently subject to spontaneous ignition

ILLUMINATING LENS A large convex lens, as it concentrates the light of the sun or a lamp at the focus, is sometimes called an illuminating lens (See *Lens*, *Burning Lens*, or *Convex Lens*)

ILLUMINATING POWER OF GAS FLAMES Professor B Silliman (*Am Jour of Science*, Feb 1870) has examined, in a lengthy series of experiments, the relation between the intensity of light produced from the combustion of coal gas and the volume of gas consumed His experiments prove, *inter alia*, the theorem, that the illuminating power of gas flames increases within the ordinary limits of consumption as the square of the volume of the gas consumed The point of chief interest for the consumer of gas to be deduced from the data here presented is, that where it is important to obtain a maximum of economical effect from the consumption of a given volume of illuminating gas, this result is best obtained by the use of burners of ample flow

IMAGES, ELECTRIC A term applied by Sir William Thomson in connection with the mathematical theory of electric distribution to certain imaginary electrical points or group of points He shows that the effect by induction of an electrified body upon an insulated conducting sphere, is represented by the "image of the body in the sphere," and that when an electrified body is brought near to a pair of insulated conducting spheres, the effect of it upon them, and of them upon each other, is represented by the series of "successive images" formed by it in them For information on this subject see the original papers of Thomson, *Cambridge and Dublin Mat Jour*, 1849, Liouville's *Journal de Mathematiques*, 1845; and Thomson and Tait's *Natural Philosophy*, vol 1, §§ 512 518

IMAGES, ELECTROGRAPHIC A name given to certain figures discovered by Riess They are produced on a plate of glass by putting it between two points connected with the poles of a battery The glass is observed to become disintegrated in lines which proceed from the points The same is found to be the case with regard to mica and some other substances

IMAGES FORMED BY MIRRORS See *Mirrors*, *Images*, *Virtual*, *Real*

IMAGES, VIRTUAL, REAL (*Imago*, an image, from *imitor*, to imitate) A virtual image is one which is not formed by the actual union of rays in a focus, and cannot be received upon a screen, a real or positive image is one formed in the focus of a mirror or lens, and can be received on a screen An image seen in a looking glass or in a convex mirror is a virtual image, whilst the image formed in the focus of a concave mirror or a convex lens is a real image. (See *Mirrors*, *Lens*, *Focus*.)

IMMERSION (From *immergo*, to plunge under) The disappearance of any celestial body, whether in eclipse or occultation The term is commonly limited to the occultations of Jupiter's satellites, and of stars by the moon

IMPACT (*Impactus*, part of *impingo*, to strike against) In mechanics, the shock of two bodies that come together, one or both of which are in motion, or the simple action of one body upon another, by which the motion of the latter is produced or altered It is a matter of observation that when one body impinges directly on another, the velocity of the first is diminished, and that of the latter increased, by the impact, the first will have lost momentum, and the second will have gained momentum Now momenta lost and gained are what are termed in Newton's Third Law (see *Laws of Motion*) action and reaction, and these he ascertained by numerous experiments to be equal Hence the momentum lost during impact by one body is equal to that gained by the other. The nature of the action during impact may be thus described When the first body A overtakes the second B, both will be compressed so long as A moves faster than B, and the compression will cease when the velocities are rendered equal, if the action stops here the bodies are said to be inelastic In this case the velocity after impact will be found by dividing the sum of the momenta before impact by the sum of the masses of the bodies Generally, however, another force comes into play when the velocities are equal, and the bodies begin at that instant to recover their figure, and to exert one upon the other a pressure which lasts until impact ceases Thus A not only loses momentum during compression, but also during expansion. Now it is found by experiment that the momentum lost by A and

gained by B during compression bears to the momentum lost by A and gained by B during expansion a ratio, which is constant for the same materials This ratio is termed the modulus of elasticity A body is inelastic when the modulus is o, it is perfectly elastic when the modulus is 1, and imperfectly elastic when the modulus lies between o and 1 (See *Elasticity*)

IMPENETRABILITY (*Impenetrabilitas*, from *in*, not, and *penetrabilis*, penetrable) A property of matter by which only one body can at any instant occupy a certain space It is one of the essential properties of matter, and it needs no demonstration, as it is inconceivable that two different bodies should simultaneously occupy the same space Cases of apparent penetration are due to compression or to displacement, produced in each instance under well-defined laws (See *Compressibility*, *Density*, *Specific Gravity*)

IMPERIAL GREEN See *Acetates*, *Aceto-Arsenite of Copper.*

IMPETUS (*Impetus*, from *in*, and *peto*, to urge, to rush) A term synonymous with momentum, the force of a moving body The term has a special application in gunnery, meaning the altitude through which a heavy body must fall to acquire a velocity equal to that with which the ball is discharged (See *Momentum*)

IMPONDERABLE (*In*, and, *pondus*, weight, from *pendo*, I weigh) Not having sensible weight In the early theories of physical science, light, heat, electricity, and magnetism were regarded as substances, and as they are without perceptible weight they were termed the imponderables

IMPULSE (*Impulsus*, driven, from *impello*, to drive) The single or momentary force with which a body is impelled by another body striking it The strictly mathematical definition of an impulse is the limit of a force which is infinitely great, but acts only during an infinitely short time There are, of course, no forces in nature exactly fulfilling the conditions of this definition, but there are forces which are very great and act only during a very short time, as, for example, the blow of a hammer Such forces are treated as impulses, they are measured by the whole momentum generated by the impulse

INCIDENCE, ANGLE OF (*In*, upon, and *cado*, to fall) The angle of incidence is the angle which a ray of light falling on a surface, forms with the perpendicular to that surface, or to it tangent if curved. The angle of incidence and the angle of reflection are always equal. (See *Reflection*)

INCLINATION COMPASS See *Dipping Needle*

INCLINATION, MAGNETIC Another name for Magnetic Dip (See *Dip*)

INCLINATION OF AN ORBIT The angle at which the plane of an orbit is inclined to the ecliptic

INCLINED PLANE One of the simple machines It consists of a plane surface inclined to the horizon at an angle less than 90° When a body is placed on a plane the resistance of the plane is exerted at right angles to the plane Consequently this resistance alone cannot support the weight unless the plane be horizontal A body at rest on an inclined plane must be acted on by at least three forces, the weight, the pressure of the plane, and a third force. If the plane be rough this third force may be the friction between the surfaces, if the plane be smooth it must be an external force In this case the force in the direction of the plane which will support the body is found by multiplying the weight by the rise of the plane in a given length and dividing by the length For example, if the rise be 3 feet in 100 feet the weight will be supported by a power equal to $\frac{3}{100}$ of the weight This quantity may be termed the pressure exerted down the plane by the weight In order that the body may move up the plane the power must exceed the pressure down the plane If the plane be rough the power must exceed the sum of this pressure and the force of friction

INCLINOMETER Another name for the *Dipping Needle*, which see.

INDEX OF REFRACTION See *Refraction, Index of*

INDIA RUBBER See *Caoutchouc*

INDIGO (ἰνδικόν, deep blue) An organic colouring matter, obtained from the leaves of various species of indigofera, its lustre is dark coppery red, semi-metallic when in mass, and deep blue in powder. It sublimes at about 290° C (554° F) in dark purple vapours, condensing in six sided prisms When in contact with a solution of alkali and a reducing agent it is converted into indigo white, which dissolves in the alkali White cloth dipped into this solution and then exposed to the air becomes dyed with indigo blue by absorption of atmospheric oxygen and carbonic acid The formula of indigo blue is C_8H_5NO, and that of indigo white $C_{16}H_{12}N_2O_2$

INDICES OF REFRACTION OF OPAQUE BODIES See *Opaque Bodies, Indices of Refraction of.*

INDIUM. A rare metallic element discovered by Reich and Richter by means of spectrum analysis in some zinc ores Its spectrum exhibits two indigo coloured lines in the more refrangible part of the spectrum. It is a very soft lead coloured metal, easily beaten out into

leaves, and tolerably permanent in the air, it much resembles lead in its physical properties The compounds of indium impart a violet tint to flame

INDUCED CURRENT See *Current, Induced*

INDUCTION COIL, or, *Ruhmkorff's Coil*, as it is very generally called, is an apparatus for producing currents by induction, (see *Induction, Electro-Dynamic*, *Current, Induced*), and utilising them It consists essentially of two coils wound on to a hollow cylinder, within which is a *core*, as it is called, formed of a bar of soft iron or a bundle of soft iron wires One of the coils, called the *Primary Coil*, is connected with the battery by means of an arrangement for making and breaking connection with it, so as to produce temporary currents, the other, the *Secondary Coil*, is wound round the first, and in it is generated a current by induction every time the current begins or stops in the primary coil (See *Current, Induced*) The currents produced by induction possess high power of overcoming resistance as well as great quantity, and hence very intense effects, chemical, and physiological, and luminous, are obtainable from them The details of the construction of Ruhmkorff's coil are as follows —The *primary* or *inducing* wire is thick, and only a few yards long, in order that the current may not be much weakened by resistance It is coiled on a cylinder made of cardboard, and besides, being covered as usual with silk for insulation, is insulated by being enclosed in a glass cylinder, or covered with a coating of shell-lac or gutta percha The *secondary* coil is wound round the primary coil It is made of the very finest wire, and is frequently many miles long It is very carefully insulated at all parts, being covered with silk, and each layer of wire, to insulate it from those within and without it, is served with a coating of melted shell lac or gutta-percha This perfect insulation is a matter of the greatest importance Within the cylinder of cardboard is placed the *core*, a bundle of soft iron wires having the ends projecting slightly beyond the extremity of the cylinder The *current break* is connected with one of these extremities, it consists of a small soft iron *hammer* which is generally kept pressed down upon the *anvil*, a second piece of soft iron, by means of a spring, when in this position the current, which is to flow from the battery into the primary coil, passes along the hammer, down through the anvil, and so proceeds on its course, but the moment it enters the primary coil, it magnetises the bundle of soft iron wires, and the extremity of these, which projects beyond the cardboard cylinder, thereupon attracts the hammer, raises it from the anvil, and thus stops the current The current being stopped, the iron core at once loses its magnetism, and the hammer falls under the influence of the spring, reopens the way for the current from the battery, and so the action goes on, the hammer oscillating with great rapidity while the coil is at work Each time the battery connection is made or broken, a powerful current is obtained in the secondary wire, which manifests itself in sparks or some other form of discharge between the extremities of it These, on coming out of the coil, are brought to binding screws, insulated on glass pillars, and thence, by proper connections, to any required place

A *commutator* or *battery key* is attached to the apparatus, so that the current from the battery may be sent into the primary coil in either direction, or cut off altogether

M Fizeau very much increased the power of the induction coil by adding to it a *condenser* This consists of two very large surfaces of tinfoil, insulated from each other by oiled silk, and the tinfoil and oiled silk rolled up for convenience of form One of the tinfoils is attached to the wire from the battery before it enters the primary coil, the other after it emerges from it The object of it is to condense the *extra current*, which occurs on breaking the battery connection, and diminishes the suddenness with which the current in the primary coil ceases, the induced current is thus made shorter, and more intense

The effects of the induction coil are very remarkable Using a battery of three or four Bunsen's elements, it is necessary to be very careful not to allow the discharge to pass through the body. Small animals may be easily killed with two cells, and a larger number would be dangerous to a man The spark, when taken between two points, may readily be made to pass through a glass plate, a quarter of an inch thick or more Large Leyden jars or batteries may be charged almost instantaneously It is easy also to melt fine wires by connecting the extremities of the secondary wire by means of them, and great heat and light may be obtained by passing sparks between two charcoal points at a small distance from each other

The largest coil that has ever been constructed was made for the Royal Polytechnic Institution, under the direction of Mr J H Pepper The primary wire is 3770 yards long, and makes 6000 revolutions round the soft iron core, being arranged in 3, 6, and 12 strands The total resistance of it is 2 2 B A units The secondary wire is 150 miles long, is covered with silk throughout, and has a resistance of 33,560, B A units An account of experiments with it by Mr J. H Pepper will be found in the *Proceedings of the Royal Society* for June 1869

INDUCTION, ELECTRO-DYNAMIC, or, *Current Induction*. The action according to

which the production or stoppage of an electric current in a wire produces a momentary current or electric pulsation in a second wire adjacent to the first (See *Current, Induced*)

INDUCTION, ELECTROSTATIC A term employed to designate a mode of action of electricity on which a vast number of, indeed, we may say all, electrostatic phenomena most closely depend It is, in fact, only on account of induction that we can observe electricity at all, every manifestation, whether of attraction and repulsion, of charge and discharge, or whatever it may be, is preceded by and dependent on electric induction The subject is, therefore, of the highest importance, and we refer our readers for fuller details than our limits in this work permit, to the papers of Faraday in his Experimental Researches, 1837, *et seq*

The electric force is essentially *polar* Whatever be the explanation of its existence, whether it depends upon two fluids or one fluid, or whether it be only an affection of matter, we know of two distinct modes of the force, and hence come our ordinary *conventional* phrases, "positive electricity" and "negative electricity" Now, in no case is the one kind of force found without the other If, under any circumstances, the positive force be exhibited, an equivalent negative force is called into action

To show the inductive action, let an insulated and positively charged conductor be brought into the vicinity of another conductor, likewise insulated but uncharged If the latter be furnished with pith-ball indicators at each end they will be seen to diverge more and more as the charged body approaches, and on examining the ends it will be found that the side of it nearest to the charged body is negatively, and the remote side positively electrified, if the charged conductor be either removed or discharged the disturbance ceases, and the original neutral condition of the other is restored Thus it appears that an uncharged conductor, under the influence of an electrified body, assumes an excited state, one side of it being electrified similarly, the other oppositely, to the charged body This propagation of electric force across a non-conducting medium is called *induction*

Let a number of uncharged insulated conductors be placed in a row, and let a charged body, which, for definiteness, we shall suppose to be positively electrified, be brought near to one end of the row Then the first becomes excited in the manner already described, the side near to the influencing body being negative, the opposite side positive The positive electricity at the end of the first of the row acts by induction on the next, and makes the near end negative, the remote end positive The action is propagated still further, and, finally, the last of the row is affected, the side nearest the last but one is electrified negatively, the remote side positively Nor does the action stop here, for the positive electricity, thus developed at the remote end of the row, acts inductively towards all the surrounding objects—it may be the floor, walls, and ceiling of an enclosing chamber, or it may be the surface of the earth, the trees, the clouds, perhaps even towards the remotest stars, where no conductors intervene Faraday, the great investigator upon this subject and the propounder of the modern theory of induction, by a long series of experiments, detailed in his Experimental Researches (Royal Society Trans 1837-8), comes to the conclusion that matter can in no case receive an independent charge If force of one kind be developed, an equivalent amount of the other kind of force is at the same time put in action

So much for the generality of the action The law of inductive action on a conductor is this, that the side nearest to the influencing body is electrified oppositely to it, the side remote from it is similarly electrified Hence it follows that if a conductor, while under the influence of the charged body, be touched, or put in connection with the ground, the opposite kind of electricity to that of the charged body will flow to the earth, for the earth and the touched body are, for the time, made one and the same body, and, if now the connection be again broken, the body which was formerly uncharged is found to possess a permanent charge of the kind of electricity opposite to the influencing body

The electricity thus developed is further capable of re-acting inductively upon the charge in the first body, drawing towards itself the electricity on it, and, as it is called, making it *latent* or *dissimulated* This is the principle of the action of the Leyden jar and condenser (*q v*)

The electricity induced by an electrified body on surrounding conductors is equal in amount to that on the inducing body To show this, Faraday performed the following experiment — He took an ice pail, insulated it, and connected it to a gold leaf electroscope, and, having charged an insulated ball, he lowered it into the ice pail As the ball was lowered, electricity was driven to the outside, according to the principles we have laid down, and thence, of course, to the gold leaves which diverged The divergence increased as the ball went lower for some time in fact, till the ball had become practically covered by the ice pail, when it ceased to do so Finally, the ball was lowered till it touched the bottom, and it was found that the divergence of the leaves did not in the slightest degree increase on contact taking place. The ball, when drawn up without touching the sides, proved to be completely discharged

To Faraday our present theory of induction is due It was formerly considered that the inductive action is altogether independent of the medium across which it takes place induction was said to be the action of electricity at a distance, and the office of the insulator between the two conductors was held to be simply that of acting as a barrier across which the opposite electricities could not pass to neutralise each other Hence induction was always spoken of as acting in straight lines, an assumption which Faraday proved experimentally to be false Faraday put forward the theory, and since the publication of his *Experimental Researches* it has come to be generally held, that induction takes place *by means of* the intermediate particles of the insulating medium or *dielectric*, as he calls it The particles of the dielectric act just as the row of insulated cylinders which we supposed above The near side of each becomes charged oppositely to the inducing body, the remote side similarly, and thus the excitement is propagated from particle to particle to any distance whatsoever Now, the medium being so intimately concerned in this action, we might expect to find differences with respect to it in different media so Faraday argued, and from this consideration arose his great discovery of *specific inductive capacity* For in some media the polarisation takes place with greater completeness than in others, and thus the electric force displays itself with greater intensity across some media than across others We have given an account of Faraday's experiments on this subject, and of his results under *Capacity, Specific Inductive* Again, the polarised condition is to be considered as a forced state, and here again we meet with great differences For in some media the arrangement is such as to allow the molecules to sustain this forced or strained condition, while in others polarisation readily takes place, but the molecules very readily discharge into each other This constitutes the difference between *insulators* and *conductors* Conduction Faraday considers to be the discharging of contiguous particles one into another, brought on by previous inductive influence

For further details and for arguments in support of this theory we can only refer once more to Faraday's original papers

INDUCTION, MAGNETIC If a mass of soft iron be brought near to a magnet it becomes itself temporarily possessed of all the properties of a magnet For instance, let a small cylinder of soft iron be suspended by attraction from one end of a magnet it will be found that a second cylinder when put in contact with the first can suspend itself from it, and a third and fourth perhaps in the same way The cylinders have thus for the time being, a power of attracting similar to that of the original magnet The attractive power may even be developed in a mass of soft iron without actual contact Thus, if a bar of soft iron be placed with one end just above a plate on which a few iron filings are strewed, on bringing a powerful magnet near to the other end of the bar the filings will rise up and stick to the bar In either of these cases, when the magnet is withdrawn, the soft iron immediately returns to its natural condition and retains no trace of magnetism This action, by which a magnet develops magnetism in the soft iron, is termed *Magnetic Induction*

INDUCTIVE CAPACITY See *Capacity, Specific Inductive*

INDUCTIVE EMBARRASSMENT A term applied to the phenomenon of retardation caused by lateral induction in the transmission of telegraphic signals It is explained under *Electricity, Velocity of*, that an impulse, though momentary at starting, is prolonged out into a gradually rising and falling wave at the extremity of a long line This prevents rapid transmission of messages through a great length of cable, for time must be given for the first signal to ooze out of the wire before a second is sent, hence, where it is practicable, lines are not made much more than 500 miles or so long It is found preferable to re-send the messages

Sir William Thomson showed that the retardation is directly proportional to the square of the length of the line, and inversely proportional to the area of cross section of the conductor, for a given proportion between the wire and insulator, and calculated that the maximum speed attainable on a land line 2000 miles long, of iron wire a quarter of an inch in diameter, would be twenty words per minute His papers are published in the Transactions of the Royal Society, 1855, 1856, Philosophical Magazine, 1855, British Association Report, 1855, and in a letter to the Athenæum, Nov 1, 1856

INDUCTOMETER (μέτρον, a measure) An instrument used by Faraday for comparing the specific inductive capacities of various substances It consisted of three parallel metallic plates, the middle one of which was charged with electricity and acted inductively towards the others, which were insulated from each other, and were connected each with one of the gold leaves of an electroscope constructed for the purpose Plates of various insulating substances could be placed between the metallic plates and the distance between the latter could be altered at pleasure, and by comparing the distances when the electroscope indicated that the energy of induction from the middle plate to each of the others was the same, the relative specific inductive capacity of the insulator was inferred.

INDUS. (The Indian) One of Bayer's southern constellations, often associated with the Peacock under the title Indus et Pavo.

INEQUALITY. (*Inæqualis*, uneven) A term applied in astronomy to any variation in the motion of a body.

INEQUALITY, GREAT, OF SATURN AND JUPITER A variation in the motions of these bodies caused by their mutual attraction It was noticed, soon after the recognition of the laws of planetary motion, that Saturn's period was continually diminishing, while Jupiter's period was continually increasing, though to a smaller extent It was further found that Saturn's period was in excess of his mean period, calculated according to Kepler's laws, while Jupiter's period fell short of its mean value Accordingly the observed changes were such as were calculated to restore the periods of the planets to their mean value Near the end of the eighteenth century the periods of Jupiter and Saturn had assumed their mean value, but since that time Jupiter's period has continued to increase, while Saturn's has diminished. These facts were for a long time thought to be opposed to the laws of gravity But Laplace succeeded in detecting the origin of the perturbation in the action of those laws, associated with a peculiar relation which exists between the motions of Jupiter and Saturn Two revolutions of Saturn take place in nearly the same interval as five revolutions of Jupiter Hence, supposing the planets to be in conjunction at any time they will be nearly in conjunction again when Saturn has completed two revolutions So that whatever perturbations were effected at and near the time of the first conjunction, will be repeated during the second conjunction, and so on Thus there will be a gradual accumulation of similar disturbances, so far as this particular set of conjunctions is concerned, and there will result an effective disturbance of the periods of both planets, such as could not take place did conjunctions occur at less regular intervals In the course of time, however, this particular set of conjunctions shifts its place so far that contrary effects are developed It is interesting to notice how the mathematical expressions for planetary perturbation exhibit the effectiveness of such a relation of commensurability between two planetary periods as exists in the case of Jupiter and Saturn Calling the period of Jupiter J, and that of Saturn S,—then amongst the terms involved there is one in which the expression (5 J—2 S) appears as a denominator, so that 5 J being nearly equal to 2 S, this denominator is small, and the term itself therefore large, indicating the relative largeness of the resulting perturbation

INEQUALITY, MOON'S PARALLACTIC See *Lunar Theory*

INERTIA The passiveness or inactivity of matter This inertia, or perfect indifference to rest or motion is a quality of matter which stands foremost in all mechanical inquiries, and forms one of the chief distinctions between living bodies and lifeless matter The first law of motion is simply an exposition of the property of inertia, hence it is frequently termed the law of inertia

INFERIOR PLANET A planet whose orbit round the sun lies within that of the earth

INFLECTION. (*Inflecto*, in, and *flecto*, *flexum*, to bend) A term used to denote certain phenomena due to interference observed when a ray of light passes near to the edge of an opaque body (See *Diffraction*)

INSOLATION (*In*, and *Sol*, the sun) Exposure to sunshine

INSULATOR A body which does not permit electricity to pass through it or over its surface Among excellent insulators are glass, wax, shell-lac, gutta-percha, caoutchouc, ebonite, paraffin (See *Conductor*, *Electric*, *Conduction*, *Electric*)

INSULATING STOOL A kind of support much used in electric experiments It consists of a flat piece of mahogany supported on three or on four glass legs, preferably the former. The glass legs ought to be varnished with solution of shell lac in spirits of wine, in order to improve their insulating powers The insulating stool is used for setting charged bodies upon in order to prevent discharge by communication with the ground

INTENSITY OF A MAGNETIC FIELD The intensity of a magnetic field, at any point, is measured by the force which a unit magnetic pole would experience at that point, that is, a magnetic pole which placed at unit of distance from an equal pole would exert unit force of attraction or repulsion (See *Units*, *Magnetic*)

INTENSITY OF AN ELECTRIC CURRENT. (From the French, *Intensité*.) Is not unfrequently used in English books for what is properly called the *strength* of the current; the intensity of a current is proportional to the quantity of electricity that passes through any section of the circuit in unit of time

INTENSITY OF TWO LUMINOUS SOURCES, COMPARISON OF. See *Photometry*

INTERFERENCE OF LIGHT (*Inter*, between, and *ferio*, to strike) If two similar waves start from the same place, at the same time, they increase each other's intensity, and

the result is a wave of double light, but if one wave is half an undulation in advance of the other, the crest of one occupies the position of the hollow of the other, and the result is a dead level. If the intervals of starting are less than half a wave length, the result is a series of smaller waves, the magnitude of which depends upon the distance which one wave has in advance of the other. In the case of waves on the surface of water, this interference may easily be understood, and it has been found that similar phenomena obtain in the case of the ethereal vibrations which constitute the phenomena of light. The interference of the waves of light may be produced in many ways, by diffraction, or by reflection from thin plates such as soap bubbles, from grooved surfaces, such as Barton's buttons, or from minute particles such as atmospheric mist, &c. The illustration of the production of *colours from thin plates* will serve as a general explanation of interference, special details being found under the different headings,—*Newton's Rings; Newton's Scale of Colours, Grooved Surfaces, Colours of, Thin plates, Colours of, Thick Plates, Colours of.*

INTERFERENCE OF POLARISED LIGHT. See *Polarisation of Light, Colours produced by Polarised Light, Coloured Polarisation.*

INTERFERENCE OF SOUND. Strictly speaking, the expression "interference" in regard to sound, is tautological. According to the idea embraced in the "second" law of motion, a force acting on a particle produces the same or an equivalent effect, whether that particle be acted on or not by other forces. In sound, the expression interference is limited to the case in which the effort of one vibration to move a particle in one direction is partially, wholly, or more than counteracted by the effort of a second vibration, to move it in the opposite direction. The most obvious case of interference is when two series of waves are so related to one another, that a given point of the medium through which they are propagated is urged by virtue of one system of waves to occupy one extreme position, while by the other system it is urged to occupy a position as far as possible removed from the first. In this sense the two influences, or wave systems, "interfere" with one another, and the point remains at rest. This effect is actually produced when the phase difference between two wave systems is half a wave length. Then a point of maximum condensation, according to the one system, will correspond to a point of maximum rarefaction, according to the other system, the point will be subjected to two equal and opposite influences, and will accordingly be unmoved. Further, if two simultaneous wave systems differ by a half wave length, their simultaneous efforts at rarefaction and condensation will neutralise one another, so that silence will be produced. This theoretical truth can be demonstrated experimentally by dividing a wave segment into two, and making one-half traverse a path a half wave length longer than the other half. Silence ensues. A tuning fork or other sonorous body is made to sound before a trumpet-shaped tube. The sound wave going down the tube is split upon a wedge and cast right and left into branches of the first tube. The branches to the left and right are both U shaped, so that their second branches are reunited into a single tube. The tube to the left is fixed in length, that to the right can be elongated by sliding over it the convex extremity. When this extremity is so slided that the total length of the band to the right is half a wave length longer or shorter than that to the left, no sound is heard at the common extremity of the two, because the phases of the two wave systems are so related, that the maximum condensation of the one system corresponds to the maximum rarefaction of the other, and all the intermediate states of condensation of the one are coincident with the corresponding states of rarefaction of the other. The author of this article has contrived an apparatus for showing the same effect by employing a vibrating rod between the open ends of two tubes which are joined together. When the rod approaches one tube it causes a condensation on that side, exactly equal to the rarefaction on the other, so that, in all positions, there is exactly a half-wave difference of vibration in the two systems of waves.

If a rectangular rod gives rise to a system of waves when struck, the note is heard with nearly equal distinctness at almost whatever position the ear may be placed in regard to the rod. But if it be placed at the corner of the rod scarcely any sound is heard, and if such a square rod be turned round as it is sounded, four regions of silence will be detected opposite to the four corners of the rod. These regions are lines which mark the coincidence of the maximum compression due to one face, with the maximum rarefaction due to the other. The absence of sound in these lines can be well shown by turning a struck fork above a cylinder glass of such capacity that it resounds to the fork's note. (See *Resonance.*)

INTERNAL DISPERSION. See *Fluorescence.*

INTERNAL WORK OF A MASS OF MATTER. On referring to the article which treats of the *mechanical equivalent of heat,* it will be seen that Mayer deduced his determination from a calculation of the work done, and the heat consumed, by a gas expanding under a constant pressure. Gases expand far more than solids or liquids for a like increment of heat, hence

when they expand under conditions of external pressure, as in raising a piston against the atmospheric resistance, it is quite obvious that they perform a great amount of what may be called *external work* In fact, heat engines depend for their action upon this performance In the case of solids and liquids, the external work is far less, because the expansion is far less, and by work we mean weight raised through a certain space (See *Foot-Pound*) For instance, if we take a cube of iron 1 decimetre (3 937 inches) in the side, and heat it from the freezing to the boiling point of water (viz, from 32° F to 212° F, or from 0° C to 100° C), it will increase in bulk by about 4 cubic centimetres (that is, by about the bulk occupied by 60 grains of water at the freezing point), and each face of the cube will be expanded twelve hundredths of a millimetre The pressure of the atmosphere on each face will be 103 kilogrammes, hence the total exterior work done will be 618 kilogrammes (about 1360 lbs 1 kilog = 15432 34 grains) raised through six-hundredths of a millimetre, which is less than one-tenth of a kilogrammetre, that is, of the work represented by the raising of 1 kilogramme through a space of 1 metre (3 280899 feet) The exterior work of solids is therefore exceedingly small, and bears no comparison with that of gases The exterior work of liquids, which may be calculated from their coefficients of expansion, the conditions of pressure being known, is also extremely small

But while in gases the force of cohesion has been entirely overcome (see *Expansion*), and in liquids is but slight, this force is considerable in the case of solids The attraction of the molecules of solids for each other determines the solid form, and if such bodies are far from their point of fusion, the force of this molecular attraction is excessively great Barlow has calculated that a bar of wrought iron a square inch in section requires a weight of a ton to stretch it $\frac{1}{10000}$ of its length In the case of the cubic decimetre of iron mentioned above a force of 250,000 kilogrammes would be necessary to produce the lengthening of twelve-hundredths of a millimetre, yet this is effected by raising the same mass through 100° C, and the wrought iron bar may be expanded through the length, for which by direct strain 1 ton is necessary, by heating through 9° C (16 2° F) The fact is, that in expanding bodies, heat has to overcome the attraction of the molecules, and in so doing it performs *internal work* Before the molecules can be separated their cohesion must be combated, and as the cohesive force of the molecules of different substances varies in intensity, so does the expansion for the same increment of heat vary (See Table given under *Expansion*) As heat disappears in the performance of mechanical work, it follows that when we heat a substance the heat is distributed into three parts, one portion disappears as heat, and becomes mechanical force, necessary for overcoming the external resistance which the substance undergoes in changing its dimensions, in fact, it performs the *external work* A second portion of the communicated heat disappears as heat and becomes mechanical force necessary for overcoming the internal resistance, that is, the cohesive force of the molecules, in fact, it performs *internal work* The rest of the communicated heat remains as *sensible heat*, and raises the temperature of the substances

Now we know the amount of heat which represents a definite amount of mechanical work, and *vice versa* (see *Mechanical Equivalent of Heat*), and the amount of heat which disappears in the performance of interior work can thus be determined When a pound of iron is heated from 32° F to 212° F it has been calculated that the force expended in interior work is equal to 16,000 foot pounds, that is, it could raise 7 14 tons to a height of one foot, or 1 lb to a height of 9 miles

In speaking of expansion, it has been stated that certain crystalline bodies contract in one direction when they are heated, we know moreover that water near the freezing point contracts when heated (See *Expansion, Maximum Density of Water*) Water possesses the same volume at 3 5° C that it does at 4 5° C, hence in heating it from one temperature to the other, it is quite obvious that the heat which disappears as internal work is not expended in overcoming the cohesive force of the molecules by separating them, this also applies to bismuth and to certain crystalline bodies In these instances it is probable that the internal work consists in an alteration of the arrangement of the individual molecules unaccompanied by an alteration of their relative distances, such as a rotation of the molecules around their axes, or some other movement of individual molecules not affecting the space occupied by a congeries of them

In liquefaction and vaporisation heat disappears, and is converted into interior work (See *Latent Heat*) Again, it is obvious that as the number of molecules in equal weights of different substances varies greatly, and as their cohesive power also varies, the consumption of heat in internal work must also vary, and hence the *absolute quantities* of heat possessed by different substances are not indicated by their temperatures (See *Specific Heat*)

INTRINSIC LIGHT (*Intrinsecus, intra*, within, and *secus*, side) Intrinsic light is in contradistinction to borrowed light Thus the sun, a candle, a Geissler's tube, or a glow-worm shine by intrinsic light; but the moon and most natural objects shine by borrowed or reflected light.

INVERSION, THERMO-ELECTRIC. See *Thermo-Electricity*.

INVERTED SUGAR A mixture of dextrose and lævulose produced by the action of acids or heat upon cane sugar (See *Sugar*)

INVERTING PRISM See *Right-Angled Prism*

IODINE (ἰοειδής, violet-coloured) An element belonging to the chlorine group, discovered by Courtois in 1812 Atomic weight 127, symbol I At the ordinary temperature it is a solid grayish, black, metallic-looking crystalline mass, very soft and brittle. It volatilises at the ordinary temperature, and when heated to 107° C (224 6° F) it melts, and at a temperature between 175° and 180° C (347°-356° F) it boils, evolving a magnificent violet-coloured, very dense vapour Iodine dissolves largely in disulphide of carbon, to a less degree in alcohol and ether, and also in solutions of alkaline iodides, and other salts Water dissolves it very sparingly In its chemical properties iodine resembles chlorine, but it possesses less intense affinities Its principal compound is with hydrogen (see *Hydriodic Acid*), and with the metals (see their respective headings) It also unites with nitrogen, chlorine, bromine, oxygen, and various organic bodies The most important of these compounds are the following —

Iodide of Nitrogen This name is given to a substance the composition of which is not satisfactorily ascertained, and which is probably a mixture of several substances, perhaps containing hydrogen It is a brownish black powder, precipitated by adding a solution of iodine to ammonia, and also formed by digesting iodine in strong ammonia It must be dried in small portions, on separate pieces of filtering paper, by exposure to the air When dry, iodide of nitrogen is one of the most explosive substances known, the slightest touch even with the end of a feather causing it to explode with a sharp report, shattering to pieces the solid body upon which it rests If cautiously liberated from the paper, and allowed to fall from the height of a few feet into a basin of water, the shock is sufficient to induce explosion Its explosion is attended with the evolution of a beautiful violet vapour of iodine Many reagents, such as sulphuretted hydrogen or sulphurous acid, decompose it slowly

The only oxygen compounds of iodine which need be mentioned are iodic and periodic acids

Iodic Acid I_2O_5 in the anhydrous state, and HIO_3 in the hydrated state This crystallises from its solutions in transparent six-sided tables It is very soluble in water, and possesses the properties of a strong acid It is easily decomposed by reducing agents With bases it forms salts, which, however, need not be mentioned further

Periodic acid (anhydrous I_2O_7, hydrated HIO_4) forms colourless deliquescent crystals, which decompose easily Its compounds with bases are well defined, but of no particular interest

IODO QUININE, SULPHATE OF A salt of which the composition is somewhat doubtful, first prepared by Herapath It forms large flat crystals, exhibiting by reflected light an emerald-green metallic lustre By transmitted light they are almost colourless, being of a faint neutral tint These crystals possess the rare property of allowing only one polarised ray of light to pass, exerting an action upon light in this respect similar to a plate of tourmaline, or a Nicol's prism On this account they are largely used in optical experiments, and usually go by the name of *herapathite* or *artificial tourmaline* The salt is prepared by dissolving acid sulphate of quinine in strong acetic acid, and gradually dropping in an alcoholic solution of iodine After a few hours the crystals separate in large plates (For further particulars see Herapath's paper in *Journal Chem Soc*, xi 130)

IOLITE See *Dichroite*

IONS (ἰόν, that which goes) A term introduced by Faraday to designate the two portions into which an electrolyte splits up under the influence of the electric current, and which go one of them to the positive electrode, or, as he calls it, the *anode*, and the other to the negative electrode, or *kathode* The former he calls the *anion*, the latter the *kathion* (See under those names and *Electrolysis*)

IRIDESCENCE (ἶρις, the rainbow) Exhibition of prismatic colours This term is usually applied to the phenomena of interference colours, shown by grooved surfaces or thin films, thus we speak of the iridescence of mother of pearl and of a soap bubble (See *Barton's Buttons*, *Diffraction Spectra*, *Grooved Surfaces*, *Colours of*, *Colours of Thin Plates*)

IRIDIUM (ἶρις, the rainbow) A somewhat rare metallic element found in association with platinum It was discovered in 1804 by Tennant in the residue left on dissolving crude platinum in nitro-hydrochloric acid, in which it occurs in an alloy with osmium, and hence sometimes called iridosmine. From this it is separated with great difficulty The atomic weight of iridium is 99 13, and its symbol Ir In the pure compact state after fusion it is a bright white metal, very dense (specific gravity 21·15), brittle in the cold, but malleable at a red heat, unacted upon by all acids, and infusible in the ordinary oxy-hydrogen blowpipe Deville however, has succeeded in fusing it in his lime furnace, fed with a powerful oxy-hydrogen blast

Iridium, alloyed with platinum, renders it harder, somewhat less fusible, and less affected by gas flames and chemical reagents. Hence this alloy is sometimes used instead of pure platinum for chemical utensils The compounds of iridium with chlorine and acids assume many colours, hence the name given to it by the discoverer

IRIS That portion of the eye which surrounds the pupil It owes its name to the different colours—various shades of blue, brown, or gray—it assumes in different persons (See *Eye*)

IRIS ORNAMENTS See *Barton's Buttons*

IRISCOPE (ιρις, the rainbow, and σκοπεω, to view) A philosophical toy by which Newton's coloured rings can be readily seen It consists of a plate of black polished glass, cleaned so perfectly that vapour is deposited on it in a continuous film On breathing through a glass tube upon the surface, coloured rings appear, owing to the different thicknesses of the aqueous film deposited The order is that of Newton's scale reversed, as the film is thinnest at the margin and thickest at the centre (See *Newton's Rings*)

IRON A metallic element very widely diffused in nature, and occurring in great abundance in many parts of the world Its symbol is Fe, from the Latin word *ferrum*, and its atomic weight 56 In the perfectly pure state iron is almost unknown, its preparation being attended with enormous difficulties , but, from the researches of Dr Matthiessen, it appears to be softer than ordinary wrought iron, of silver whiteness, capable of taking a high polish, and very tough Its specific gravity is 7 8439 Electrotyped iron has been found to have a specific gravity of 8 1393 In the purest attainable state, iron is scarcely acted on by acids In the arts, iron is met with in the forms of malleable iron, steel, and cast iron The first being iron, as free from impurities as it is possible to get it, and the other two being iron, containing carbon, in proportions varying from 0 65 to upwards of 5 0 per cent Good malleable iron, known also as wrought iron, is of a grayish colour Its specific gravity is about 7 8 Its melting point approaches that of platinum , although at temperatures far below this, it assumes a soft pasty condition, and is capable of being welded together into one mass This property of iron is of the greatest value in manufacturing operations Its hardness and toughness are scarcely altered by heating to redness, and cooling suddenly, forming in this respect a striking contrast to steel and cast iron It is very malleable and ductile, and at a red heat may be hammered and rolled into any desired form By these operations it acquires a fibrous texture, and increases greatly in tenacity The presence of foreign substances modifies the working properties of wrought iron thus, sulphur in quantities of upwards of 0 01 per cent renders it what is technically called "red short"—that is, brittle and non tenacious at a red heat Phosphorus, if present in quantities of more than 0 5 per cent , renders the iron brittle at the ordinary temperature, or, as it is technically called, "cold short" In dry air malleable iron is unchanged, but air and moisture quickly oxidise it, forming a red rust, which in time would eat through the whole mass When heated to whiteness in a current of air, malleable iron burns with vivid scintillations, producing magnetic oxide, and at a red heat decomposes aqueous vapour, forming magnetic oxide and evolving hydrogen (See *Hydrogen*)

Steel is intermediate between malleable iron and cast iron, and its peculiar properties are supposed to depend upon the amount of carbon combined with it The best steel contains about 1 5 per cent, and when the carbon gets below this it becomes "mild steel," and approaches wrought iron in its properties, whilst when the carbon increases beyond this amount it assumes the properties of cast iron The distinguishing property of steel is that of becoming very hard and brittle when it is heated and then plunged into water, and of becoming soft again when heated and cooled slowly When hardened steel is gradually raised in temperature and a bright surface is watched, it will be seen to pass through different shades of colours which are due to different thicknesses of oxide (See *Thin Plates, Colours of*) These colours have been found to correspond to definite temperatures, and if the steel is plunged into water at any particular colour it will be found to possess a definite amount of temper, as it is called, dependent upon the temperature which it had attained The following table gives the colour assumed by the surface, the temperature to which this colour corresponds, and the kind of tool or instrument to which this particular temper is best suited.

Temperature	Colour	
220° C (430° F)	Faint yellow	Lancets
232° C (450° F)	Pale straw	Best razors and most surgical instruments
243° C (470° F)	Full yellow.	Common razors, pen knives, &c
254° C. (490° F)	Brown.	Small shears, scissors, chisels for cutting *cold*, hoes
265° C (510° F)	Brown, dappled with purple spots.	Axes, plane irons, pocket knives.

Temperature	Colour	
277° C (530° F)	Purple	Table knives, large shears
288° C (550° F)	Light blue	Swords, watch springs, bell springs
293° C (560° F)	Full blue	Fine saws, daggers, augers
316° C (600° F)	Dark blue	Hand and pit saws

Good steel is white in colour and takes a very high polish Its fracture should be close and granular, with no appearance of fibre Its tenacity exceeds that of any other metal or alloy Its specific gravity varies between 7 6224 and 7 8131 It melts at a lower temperature than malleable iron, being more fusible in proportion to the carbon it contains When near the melting point it is capable of being welded and wrought When dissolved in acids it leaves a black carbonaceous residue Steel is produced either by adding carbon or a highly carbonised iron to malleable iron, as in the cementation process, or by removing carbon from cast iron, as in the processes of making natural steel, puddled steel, and Bessemer steel A description of these different processes would occupy too much space, and the reader is therefore referred to works on metallurgy for further details

Cast Iron or *Pig Iron* is iron containing the highest amount of carbon There are two kinds, viz, gray and white cast iron Gray cast iron is granular in texture and of a gray colour Its fracture is fine grained, and on close examination particles of graphite may be detected in it Its specific gravity is about 7 1 It melts at about 1600° C and becomes very liquid, passing suddenly from the solid to the liquid state When rapidly cooled it is converted into white cast iron

White cast iron is much whiter than gray cast iron, it has a crystalline and somewhat conchoidal fracture, and is very hard and brittle Its specific gravity is about 7 5 It melts at a little lower temperature than gray cast iron, and before becoming liquid it passes through a pasty condition When cooled very gradually it is changed into gray cast iron The most characteristic kind of white cast iron is Spiegeleisen or Specular Iron The chief difference between these two kinds of cast iron appears to be due to the state in which the carbon is contained in them In white cast iron it is supposed to be in chemical combination, whilst in gray cast iron the greater part is mechanically diffused through it in the form of graphite The carbon may be removed from cast iron by heating it to the welding point and stirring it about in the air or with oxide of iron (*Puddling Process*), or by blowing air through it in the melted state (*Bessemer Process*) In the latter operation the heat produced by the combustion of the carbon is sufficient to raise the temperature to such a degree that when at last the carbon is all burnt off the resulting malleable iron is still in the liquid state If these operations are stopped before all the carbon is burnt off, steel of various qualities is produced Besides carbon, which may be considered a normal ingredient, cast iron contains other impurities, of which sulphur, phosphorus, and silicon are almost always present, whilst manganese, copper, aluminium, calcium, magnesium, arsenic, nickel, cobalt, titanium, vanadium, chromium, zinc, antimony, &c, occur less frequently Cast iron is the form in which the metal is almost invariably prepared from its ores A mixture of iron ore, (see *Iron Ores*,) limestone, coke, and sometimes other substances to form a fusible slag, is piled up in enormous quantities in blast furnaces, sometimes nearly 100 feet high, and after being ignited below, the heat is brought to its greatest intensity by forcing in blasts of air by means of powerful pumps, and through blow pipe nozzles two or three inches in diameter The blast is sometimes at the ordinary temperature, but more frequently heated to about the melting point of lead Reduction of the iron to the metallic state rapidly takes place, whilst the other constituents form a fusible slag through which the iron falls and collects in the lower part of the furnace, the slag forming a liquid layer over it As the slag accumulates, it is allowed to flow from an aperture above the level of the liquid iron, and when the iron has accumulated to a certain height it is tapped off at the lower part whence it flows in a stream along channels prepared for it in the sand with which the floor of the shed is covered The chemical reactions which take place in a blast furnace are very complicated, and are not yet thoroughly understood The reduction of the oxides of iron is effected by the carbonic oxide at a temperature lower than the melting point of iron, and the materials with which the blast furnace is fed are so proportioned that the amount of silica, alumina, and lime shall be present in the proper proportion to form a double silicate of lime and alumina This double silicate being fusible below the melting point of iron, coats the reduced spongy metal as with a varnish and prevents its reoxidation whilst its temperature is rising to the fusing point.

The gases which issue from the top of blast furnaces consist of between 50 and 60 per cent of nitrogen, about 10 per cent of carbonic acid, 25 per cent of carbonic oxide, the remainder being a mixture of marsh gas, olefiant gas, and hydrogen Formerly they were allowed to burn at the mouth of the furnace, but latterly they have been drawn off and utilised as fuel for heating boilers, puddling furnaces, &c.

Oxides of Iron Iron forms several oxides, the most important being the protoxide, the sesquioxide, and the magnetic oxide

The Protoxide or Ferrous Oxide (FeO) is scarcely known in its pure or hydrated state It is a powerful base, forming salts, which are for the most part soluble in water, easily crystallisable, of a pale greenish blue colour, and white when anhydrous Those of any importance are described under the headings of their acids

Sesquioxide of Iron, or, *Ferric Oxide* (Fe_2O_3). This is very widely distributed in nature, and in the form of hæmatite and specular iron is one of the most important ores of iron When anhydrous, and prepared artificially, it is an amorphous powder, varying in colour from bright red to dark brown When prepared by igniting the magnetic oxide it is magnetic, but generally it has no magnetic properties, it is reduced to the metallic state by hydrogen, carbon, carbonic oxide, and combustible gases, at a red heat Sulphuretted hydrogen reduces and sulphurises it In the hydrated state it is a yellowish brown earthy looking powder, which becomes anhydrous at a red heat, and is reduced more easily than the anhydrous oxide Sesquioxide of iron dissolves in acids, forming salts which are generally difficultly crystallisable The most important of them will be described under the headings of their acids

Magnetic Oxide of Iron (Fe_3O_4). When native this is the richest ore of iron, it is formed artificially when aqueous vapour is passed over red hot iron, or when iron is burnt in oxygen It may be obtained beautifully crystallised by other processes It is black, almost insoluble in acids, and attracted by the magnet It does not form salts

Sulphides of Iron There are several sulphides, those of most importance being the following —

Magnetic Sulphide of Iron occurs native in crystals of a bronze metallic lustre, it is brittle, and slightly magnetic, specific gravity 4 55, the formula is not well ascertained

Disulphide of Iron (FeS_2) is very frequently met with native, and is known as *yellow pyrites*, *cubic pyrites*, and *mundic*, and when in a different state of crystallisation, white iron pyrites or *marcasite* The yellow variety occurs in cubical crystals and forms associated therewith, its specific gravity is about 5 0, it has a bronze yellow metallic lustre, and a conchoidal fracture does not alter by exposure to air, the white variety or marcasite crystallises in pyramidal and prismatic combinations, and is often massive, its specific gravity is about 4 8, it has a very pale yellowish gray metallic lustre It oxidises readily in the air, the heat sometimes rising to such an extent as to cause combustion of the mass Iron pyrites is now used in enormous quantities in the manufacture of sulphuric acid, when ignited in the air sulphurous acid is formed, and sesquioxide of iron, containing a little sulphate of iron, is left

Carbides of Iron Combinations of carbon and iron, such as cast iron and steel, are called carbides of iron Artificial compounds of carbon and iron, in definite proportions, have been prepared

Chlorides of Iron Of these there are two —*Protochloride of Iron*, or ferrous chloride ($FeCl_2$) in the hydrated state crystallises in bluish crystals, which are readily soluble in water, and deliquesce in moist air By evaporating the solution to dryness, and heating, it becomes anhydrous *Sesquichloride of Iron*, perchloride of iron, or ferric chloride (Fe_2Cl_6) sublimes in the anhydrous state when chlorine gas is passed over hot iron turnings It forms dark brown metallic looking crystals, which sublime at a little above the boiling point of water, it deliquesces in the air, and is very soluble in water The solution of sesquichloride of iron is usually prepared in the wet way On evaporation it yields crystals, which contain water of crystallisation Sesquichloride of iron is of considerable use in the laboratory, and also in medicine It is one of the most powerful styptics known for arresting bleeding Sesquichloride of iron forms numerous double salts with other chlorides

Iodide of Iron, or *Ferrous Iodide* (FeI_2) A brown mass formed by the direct union of its elements, dissolving in water to a pale green solution, and crystallising in green deliquescent crystals It is quickly altered by exposure to air, with absorption of oxygen. No other compound of iron and iodine is known

IRON, METEORIC See *Meteoric Iron.*

IRON PYRITES See *Iron Sulphides*

IRON ORES. The most important iron ores are *Magnetite*, or *Magnetic Iron Ore*. It has a black metallic lustre, and sometimes forms mountainous masses, it contains 72 41 per cent of iron

Hæmatite Red Iron Ore, or *Oligistic Iron*. This is native ferric oxide, and occurs either crystalline or massive, and sometimes in kidney-shaped lumps When pure it contains 70 per cent. of iron

Specular Iron Ore, or Elba iron ore. This is also a ferric oxide. It is iron gray and crystalline.

Brown Iron Ore. This is a hydrated sesquioxide of iron, containing when pure 59 89 per cent of iron It is generally of a compact earthy appearance

Spathic Iron Ore, or *Sparry Iron Ore* Native protocarbonate of iron It crystallises, forming masses of a light yellowish colour When pure it contains 48 27 per cent of iron There are mountains of this ore on the continent of Europe

Clay Iron Ore This consists of a mixture of hæmatite or spathic iron ore with clay

IRRADIATION. (*Irradio*, to shine on) See *Diffraction*

IRRATIONALITY OF DISPERSION. See *Dispersion, Irrationality of*

ISINGLASS See *Gelatin*

ISABNORMALS, THERMIC Dové has published a series of maps indicating the deviation of the temperature of different regions, from the temperature due to the latitude, for different months He calls the lines joining places in which the deviation is the same *thermic isabnormals*

ISOBAROMETRIC CHARTS (ἴσος, equal, βάρος, weight, and μέτρον, measure) Charts indicating the distribution of barometric pressure over the globe Dové has used the term, however, in a different sense In Buchan's excellent Handy Book of Meteorology such charts are given for January, July, and for the year The most remarkable features in the chart for the year are (1) the existence of an equatorial zone of relatively low pressure, and (2) the great difference between the barometric pressure in high northern and southern latitudes The low antarctic barometer has been explained in several ways, Captain Maury referring it to the effect of the enormous quantity of aqueous vapour rising over the southern hemisphere He supposes this vapour to carry off towards equatorial regions a portion of the air which would otherwise add to the pressure in high antarctic latitudes The present writer has given reasons for referring the difference of pressure to that displacement of the earth's centre of gravity, which causes the southern hemisphere to be more largely covered with water than the northern This access of water would, in fact, raise the level of the seas in high southern latitudes above the mean level of the terrestrial spheroid If this view is just, barometric observations in northern and southern seas give us the means of determining the displacement of the earth's centre of gravity

ISOSCELES PRISM (ἴσος, equal, σκέλος, a leg) A prism the section of which, perpendicular to its axis, is an isosceles triangle, this and the equilateral prism are the forms usually employed to effect the prismatic decomposition of light (See *Prism*)

ISOCHEIMENAL (ἴσος, equal, and χειμών, winter) *Isocheimenal Lines* are those so traced on a chart of the earth's surface as to pass through all places having the same mean winter temperature (See *Isothermal*)

ISOCHRONISM (ἴσος, equal, χρόνος, time) The property possessed by pendulums, balance-wheels, and oscillating particles, by which they perform their oscillations, whether in longer or shorter arcs, in the same time As an illustration, let us suppose a smooth particle to be dropped into a smooth hemispherical bowl It will oscillate in an arc of a vertical circle When the arc becomes small, the time of each oscillation will be the same, hence a vertical circle is isochronic for a particle acted on by gravity for a small arc only If a particle be dropped down a cycloid (the curve traced by a point on the circumference of a circle which rolls on a straight line), the time of oscillation will be the same wherever the starting point may be On account of this remarkable property, the cycloid has been termed the isochronic curve (See *Horology*, *Pendulum*, *Balance-Wheel*)

ISOCLINIC LINE (ἴσος, equal, κλίνω, to incline) A line joining all the places on the earth's surface which have equal magnetic *inclination* or dip is called an isoclinic line Such lines are found to occupy much the same position with regard to the magnetic poles that the parallels of latitude hold with respect to the geographical poles A line called the *magnetic equator* or *aclinic line* (α priv), or line of no dip, nearly coincides with the terrestrial equator, and the other isoclinic lines are nearly parallel to it (See *Magnetism, Terrestrial*)

ISODYNAMIC LINE (ἴσος, equal, δύναμις, force) A line joining all the points on the earth's surface at which the magnetic intensity is the same is called an *isodynamic line* These lines are, roughly speaking, parallels running east and west, they do not, however, coincide with the isoclinic lines

ISOGONIC LINES. (ἴσος, equal, γωνία, an angle) A line joining all the places on the earth's surface at which the declination or angle made by the magnetic with the geographical meridian is the same. The general appearance of these lines, when laid down on a magnetic chart, is that of running nearly north and south, but with very many and very great irregularities They all converge to two points, one in the northern and the other in the southern hemisphere, called the magnetic poles, and from them these radiate (See *Magnetism, Terrestrial.*

ISOMERISM (ἴσος, equal, and μέρος, part) Bodies are isomeric when they have the same elements and the same percentage composition, thus butyric acid and acetic ether have each the composition $C_4H_8O_2$, and are called isomeric, although they are very different in chemical properties

ISOMORPHISM. (ἴσος, equal, and μορφή, form) Bodies are isomorphous when they have the same crystalline form, whilst their chemical composition is different Thus the salts of phosphoric acid, and arsenic acid, of sulphuric, and selenic acid, and the protosalts of magnesium, and zinc, are isomorphous—that is to say, their corresponding compounds crystallise in the same form

ISOTHERAL (ἴσος, equal, and θέρος, summer) *Isotheral lines* are those so traced on a chart of the earth's surface as to pass through all places having the same mean summer temperature (See *Isothermal*)

ISOTHERMAL (ἴσος, equal, and θέρμη, heat) Isothermal lines are lines drawn across a chart of the earth so as to pass through all places having a given mean temperature, whether for a given month or for the year Isothermal lines for the year are commonly called the *mean annual isotherms*, the isotherms for July and January—that is, for the hottest and coldest months of the year, are called respectively *isotherals* and *isocheimenals*

We owe to Humboldt the suggestion that isothermal charts should be constructed, and also a large mass of materials to aid in their construction Such charts are most important aids to the study of climatology, indicating as they do those great laws which, apart from latitude (as also apart from altitude), affect the climate of a country (See *Climate*) It is in particular noteworthy that whereas the mean annual isotherms exhibit a certain general uniformity, and (except in polar regions) a general tendency to coincidence with latitude-parallels, we see in the isotherals, and still more markedly, in the isocheimenals, the most striking departures from regularity In July we find the continents more heated than the ocean regions lying on the same parallels, in January the direct reverse is the case Here reference is made, of course, to the northern hemisphere, where alone continental and ocean regions are distributed pretty equally, and where also we have full materials for the construction of these charts It may be noted in passing that the terms isotheral and isocheimenal are not very happily chosen, since the winter season for one hemisphere is the summer season for the other

One of the most striking of all the features presented by isothermal charts, is the position of those isotherms which cross or pass near the British Isles in winter Instead of lying along parallels of latitude, they run so nearly north and south across Great Britain, that one may accept it as a general rule in selecting wintering places in these Isles, that a high temperature is to be sought by travelling from east to west, instead of from north to south The mean winter climate of the south-western extremity of Ireland is considerably warmer than that of Constantinople, or even Cabul on the eastern continent, or than that of Washington on the western

It would be an advantage if the use of polar projections of the two hemispheres could be introduced for isothermal charts, instead of Mercator's, which so enlarges polar regions as to make the isothermal lines in high latitudes barely intelligible

We require also charts constructed so as to indicate the range of temperature for the year, since this is a more important element of climate than even the mean annual temperature

IZAR (Arabic) A name sometimes given to the star ε Bootis It is called also Mizar, Mirach, and Pulcherrima

J

JACK (Same as French *Jacques*, James, a common name for a helping-boy, and thence any instrument supplying the place of a boy, as boot jack, and generally applied to any instrument rendering convenient though apparently slight service) An adaptation of the toothed-wheel for the purpose of raising great weights through small distances It consists of a pedestal or support, in which works some combination of mechanical powers, usually a rack and pinion (See *Rack and Pinion*) The rack is prevented from descending after being raised by the following means —A small wheel, termed a ratchet-wheel, is attached to the axle, and furnished with teeth inclined in the direction opposite to that in which it is to move, and a catch falls between the teeth as the wheel revolves The reaction of this catch is in the direction of the tangent to the wheel, and permits of the motion of the wheel in one direction only. A much greater power, though attended with a proportionally diminished range in space may be obtained by combining two or more wheels and pinions in the jack

JACOB'S MEMBRANE A delicate transparent membrane of the eye separating the choroid coating from the retina. (See *Eye*.)

JANSSEN'S TELLURIC LINES. See *Atmospheric Lines of the Solar Spectrum.*

JARGON See *Zirconium.*

JASPER See *Quartz*

JET PHOTOMETER The quantity of gas which will pass through a small aperture at a constant pressure varies with the density of the gas, and in the case of different gases the quantity which will pass is inversely as their densities Mr Lowe has constructed an instrument on this principle, it is not, however, strickly speaking a photometer, or light measurer, but an indicator of constancy of quality, so long as the quality of the gas is unaltered, the jet of flame remains of the same size (See *Photometry*)

JOINT (French, *joindre*, to join, *joint*, joined, Latin, *jungere*, to fasten together) In machinery, any contrivance by which two different parts may be united either temporarily or permanently Joints are variously constructed, one of the most useful is the universal joint, invented by Dr Hook The two axles which are to be connected terminate in semi circular pieces of iron, and the diameters are fixed upon each other crosswise, at the same time moving freely in the extremities of the semi-circles Thus either axle may change its position through a considerable angle without necessarily altering the action of the other Where the greatest possible range of motion is required, a double joint can be used, constructed on a similar principle

For other varieties of joints, see *Ball-and-Socket*

JOULE'S EQUIVALENT See *Mechanical Equivalent of Heat*

JUNO One of the *Asteroids*, (*q v*)

JULIAN PERIOD A period containing 7980 years, and therefore including an integral number of cycles of the sun (each twenty eight years), of the moon (each nineteen years), and of the indiction (each fifteen years)

JUPITER In astronomy, the fifth of the planets in order of distance from the sun, the innermost and also the noblest of the system of major planets travelling outside the zone of asteroids Jupiter's mean distance from the sun is 475,692,000 miles, his greatest, 498,639,000, his least, 452,745,000 The mean distance of the earth from the sun being 91,430,000 miles, Jupiter's distance from the earth varies from about 361,000,000 to about 590,000,000 miles The eccentricity of his orbit is considerable, being 0 048239, its inclination to the ecliptic is 1° 18′ 40 3″ He accomplishes a sidereal revolution in a mean period of 4332 5848 days, while the interval separating his successive returns to opposition, has a mean value of 398 867 days He is the largest of all the planets, having an equatorial diameter of no less than 84,850 miles His polar diameter is about $\frac{1}{17}$th less, according to some estimates, while others make the compression of his globe as great as $\frac{1}{14}$th, or even $\frac{1}{12}$th His volume exceeds the earth's no less than 1233 205 times, but his density being only about one fourth of the earth's, his mass does not exceed the earth's more than 301 times He is, however, in weight as well as in volume, the first of all the planets Indeed, he outweighs their combined mass more than doubly His rotation upon his axis is accomplished in a few minutes less than ten hours, the inclination of his equator to his orbit is only 3° 5′ 30″, so that there can be no appreciable seasonal changes in any parts of his globe

Jupiter is surrounded by a noble system of dependent orbs, having no less than four satellites (the least of which is equal to our moon in bulk) circling around his globe They were discovered by Galileo in 1610, and their motions have been ever since carefully studied by astronomers They afford to the amateur telescopist an interesting subject of study, as they pursue their career around the primary, now transiting his disc, now attaining their greatest elongation, and anon passing into his great shadow-cone Their changes of configuration are also well worthy of study Sometimes all will be seen on one side, at others, a pair on each side of the planet's disc Often he seems deprived of two or three of his attendants, while occasionally, though at very long intervals, he can be seen without any satellite external to his disc The observation of the eclipses, occultations, and transits of these satellites afford a means, though not so exact a one as was once hoped, of determining terrestrial longitudes, and accordingly the epochs at which these phenomena may be witnessed, are announced beforehand in the Nautical Almanac At present it would seem that, besides the inherent difficulties in this mode of determining the longitude, there are others depending on the inexactness of the tables of Jupiter, and it is to be hoped that, before long, better tables than Delambre's will be prepared and published. Observation of the phenomena of Jupiter's satellites affords a useful exercise to the young astronomer

It was by observations of Jupiter's satellites that the velocity of light was discovered The eclipses and other phenomena were observed to take place later than their calculated time when the planet was approaching conjunction. It was at length suggested by Romer that this is

due to the greater distance light has to travel at such times. Repeated observations have shown this explanation to be the correct one.

The disc of Jupiter is crossed by dark belts variable in breadth and figure (See *Belts*.) During the winter of 1869-70 these belts were much studied by astronomers, on account of the striking colours and changes of colour they exhibited. These changes had been noticed in the autumn by Mr Browning, the optician, who was the first to invite the attention of astronomers to their singular nature.

Much yet remains to be learned respecting the physical habitudes of this noble planet, and there is room for prolonged and patient study of his appearance, and changes of appearance. It may be reasonably questioned whether he presents even a general resemblance in physical constitution, and especially in his present physical condition, to our earth, or to any of the small planets circling within the zone of asteroids.

K

KALEIDOPHON. Wheatstone's kaleidophon consists essentially of a series of elastic steel rods of rectangular section, which can be fastened rigidly at one end into a massive support, and which carry at the other end a bright silver button, or silvered globular glass bead. The object of the kaleidophon is to show the influence of thickness upon the rate of vibration of an elastic rod, and to render visible the effect upon the rod of difference of phase of two simultaneous vibrations. If a square rod be fixed in an upright position it will vibrate as fast when its plane of vibration is parallel to one of its faces as when parallel to the neighbouring face at right angles to the first plane (see *Vibrations, Transversal, of an elastic rod*), and the bright bead at the end will appear to move in either case in a straight line. If the rod receives two equal and simultaneous impulses at right angles to one another when at rest, that is, when the phase difference is nothing, it will move in a straight line bisecting the direction of the impulses and return along the same path. Its path will, therefore, be a straight line. If when under a single impulse it has reached its point of maximum excursion it receive the second impulse at right angles to the first, there will be a difference of phase of half a complete vibration and the end of the rod will then vibrate in a straight line perpendicular to the former one. If under the influence of the first impulse it has completed half an excursion, or a quarter of a vibration, it receives the second it will move in a circle. The same will be the case if it receives the second impulse when it has completed three half excursions or three quarters of a vibration. In all other relations of phase ellipses will be described, which will remain constant if the rod be exactly square and exactly clamped. By means of a little screw working through the pedestal one side of the rod may be touched near to its extremity; this virtually shortens one side of the rod. It no longer vibrates in the two directions at the same rate. The figures no longer remain constant but collapse and expand. If the rectangular rod be twice as wide as it is thick an analogous series of figures will be described depending upon the difference of phase. The figure corresponding to the straight line (0 or ½ vibration difference) will now be an open curve resembling a parabola and having its curvature turned one way or the other, according as the vibration difference is 0 or ½. The circular path of the former case will now appear as a figure of 8 (difference of vibration ¼ or ¾). The intermediate cases will resemble the same figure having the point of intersection pushed laterally one way or the other. These figures correspond with the ellipses of the former case. As before, by means of the screw a slight difference of rate of vibration in one direction may be introduced, whereupon the figures vary as in the previous case. Similar but more complex figures are formed when other relations exist, the shape of the constant figures depending upon the numerical relation of the vibrations and their relative phases, the motion of the figures depending upon a continual change of phase. The simplest case of the first of the relations given is, of course, offered by a cylindrical rod in vibration, for such a rod must vibrate at the same rate in all directions.

By fastening one elastic rod at right angles to another at their extremities the vibration of a point in three dimensions can be examined. In this, as in the former cases, the position of the point at any given time can be calculated, and the shape of its path determined mathematically. Sir C. Wheatstone has also constructed an apparatus for illustrating the same effects when a rigid body is subjected to similar impulses. The centre of a rigid rod works in a socket joint, the upper end carries the bright bead, and the lower end is pushed backwards and forwards at a constant rate by a horizontal rod. Another horizontal rod at right angles to the first also pushes and pulls the end of the upright rod. The two horizontal rods are so connected together by two friction wheels at right angles to one another that by moving one wheel towards the

centre of the other any disproportion can be obtained in their rates of rotation, and consequently in the rates of backward and forward motion of the horizontal rods

KALEIDOSCOPE (καλος, beautiful, ειδος, form, and σκοπεω, to see) A philosophical toy invented by Sir David Brewster It consists of a tube containing two plane reflecting surfaces along its whole length, inclined at an angle of about 60° to each other, at one end is a small hole to look through, and at the other is a shallow glass cell containing fragments of coloured glass On looking through the tube towards the light, the figure in which the pieces of coloured glass happen to have fallen is apparently repeated five times, forming (with the original figure) a symmetrical pattern By turning the tube round, the pieces of glass tumble into different patterns, forming in the instrument a literally endless variety of symmetrical combinations

KAOLIN See *Silicates of Alumina*

KATHIONS (κατιὼν, that which goes down), are substances which during electro chemical decompositions go to the *kathode* They are the opposites of *Anions* (which see) and are equivalent to those otherwise named *electro-positive* bodies The kathions are the combustible bodies or bodies which correspond to hydrogen and the metals Thus water is decomposed into hydrogen and oxygen, of which hydrogen is given off at the kathode and in the kathion (See also *Electrolyte* and *Electrolysis*)

KATHODE (κατὰ, downwards, and ὁδὸς, a way, the way which the sun sets) The surface at which the current, according to common phraseology, leaves the electrolyte or body undergoing electro-chemical decomposition Combustible bodies, metals, alkalis, and bases are evolved there, it is opposite to *Anode* (which see)

KAUS AUSTRALIS (Arabic and Latin) The star ε of the constellation Sagittarius

KEEPER OF MAGNET A piece of soft iron put in contact with the poles of a magnet while not in use, in order to preserve its magnetism, is called a *keeper* In the case of a horse shoe magnet the keeper consists simply of a bar of very soft iron, large enough to stretch from one leg to the other When such magnets are used for lifting purposes the keeper is furnished with a hook to which a scale pan may be attached Bar magnets are protected with keepers by placing two or more of them side by side, parallel and with their like poles turned in opposite directions, two soft iron pieces, one at each end, join the unlike poles of a pair of magnets or of a pair of bundles

KELNER'S EYE-PIECE A negative or Huyghenian eye-piece, having the eye-glass achromatic (See *Negative Eye piece*)

KEPLERIAN SYSTEM The *Copernican System*, (*q v*), left unexplained a number of peculiarities in the motions of the planets It may, indeed, be gravely questioned whether the theory that the sun is the centre of the planetary motions would have gained acceptance among astronomers as it was presented by Copernicus There were objections to it which seemed scarcely less serious than those he urged against the Ptolemaic system, the chief being that it required artificial contrivances to account for the planetary motions It was to such contrivances, ingenious combinations of circular and uniform motions around centres of motion themselves travelling in eccentric but circular paths around the sun, that Kepler first turned his attention in endeavouring to establish the Copernican theory on a sound basis Taking the planet Mars as the most convenient for his purpose, and employing a series of observations of that planet (made by Tycho with great care, to establish a system opposed to the Copernican), Kepler tried one arrangement after another, but failed to account to his own satisfaction for the motions of the planet At length the idea occurred to him of trying elliptical orbits, traced out according to different laws of motion After spending in all more than a score of years over these apparently hopeless and unprofitable researches, he at length lighted on the laws of orbital motion which constitute the two first of *Kepler's Laws*, (*q v*) He then tried to find a law associating the periods and distances of the planets After selecting for comparison the powers of the numbers expressing these elements, it is somewhat remarkable that he should have been still unable to find the law he sought, since it may be said to lie upon the very surface of the relations he was considering After some delay, however, he succeeded in detecting the third of the laws which bear his name

It should be noticed that the modern system of astronomy deserves far better to be called the Keplerian system than the Copernican The history of Kepler affords a striking illustration of the value of researches into numerical relations when conducted thoughtfully and perseveringly It is not too much to say that but for Kepler, Newton would in all probability never have turned his unequalled powers to the problems presented by the law of gravitation

KEPLER'S LAWS A term used by astronomers to denote certain laws defining the motion of planetary bodies, and discovered by John Kepler, an astronomer, born in Wirtemberg in 1571 Before this time the system of Copernicus had been established, so that Kepler knew that the apparent motions of the planets might be explained by supposing them to move round

the sun, but it was assumed that the paths were circles He also knew from observation the proportion of the distances of the planets from the sun, but not their actual distances He had a passion for discovering analogies and harmonies in nature after the manner of the Pythagoreans and Platonists. After immense labour and an infinity of trials he found out that all appearances could be accounted for and easily represented by supposing all the planets to move in ellipses, having different degrees of ellipticity and axes in different directions, the sun being in the focus of each. Again, he discovered that if three positions of a planet separated by the same interval of time, as, for instance, a day, be taken and lines be drawn from these positions to the sun, then the areas of the two triangles formed will be equal Kepler also worked out the rule, that if we square the number of days in the time of each of the planets we obtain quantities which are in the same proportion as the numbers obtained by cubing their means distances from the sun These laws are usually stated thus —

1 The planets describe ellipses, of which the sun occupies a focus

2 The radius vector of each planet sweeps out equal areas in equal times

3. The squares of the period of complete revolution, or periodic times of any two planets are proportional to the cubes of their mean distances from the sun (See *Central Forces*)

KETONE See *Acetone*

KILOGRAMMETRE The French unit used in estimating the mechanical work performed by a machine It represents the work performed in raising a kilogramme through a metre of space, and corresponds to 7 233 foot-pounds (See *Foot Pound*)

KINEMATICS (κινεω, to move) A branch of pure mathematics, which treats of the motion of a point without reference to the forces producing the motion or the bodies moved (See *Dynamics*)

KINETICS See *Dynamics*, *Energy*, *Unit Kinetic*

KIRCHHOFF'S THEORY OF THE LINES IN THE SOLAR SPECTRUM According to Kirchhoff the black lines of the spectrum are caused by the passage of light through the vapours of bodies which, by themselves would give bright lines in the same position, when incandescent, this theory is generally accepted. (See *Fraunhofer's Lines*, *Artificial*, *Reversal* of *Sodium Spectrum*)

KOCHAB (Arabic) The star β of the constellation Ursa Minor

KOPP'S LAW OF ATOMIC VOLUMES A law first enunciated by Kopp in 1842, according to which liquids belonging to one homologous series, when compared with the corresponding liquids in other collateral homologous series, are observed to have like differences in their atomic volumes

KOPP'S LAW OF BOILING POINTS A law first pointed out by Kopp As the number of atoms of the group CH_2 increases in an organic liquid there is a remarkable regularity in the increase of temperature required to produce ebullition Thus, in the compounds of methyl and ethyl every increment of CH_2 raises the boiling point about 36° F (20° C)

KORNEFOROS (Arabic) The star β of the constellation Hercules.

KYANOL See *Aniline*

L

LABORATORY (*Laboro*, to labour) A laboratory is a room or building in which researches in chemistry or natural philosophy are prosecuted, or in which those sciences are practically taught Old writers employ the term *elaboratory*, and it is obvious that this word passes by an easy phonetic change into our present word In an observatory systematic *observations* are made of external objects or phenomena, Nature is examined precisely as she presents herself to us, and is not subjected to any of the operations of science In a laboratory, on the contrary, *work* in connection with physical actions, and with matter, is added to observation, with a view to the better elimination of error, and the accumulation of just result The agencies which produce the various phenomena of the Universe, and the matter with which they associate themselves, are here submitted to numberless operations, the modes of action, together with the intensity and duration of the actions are varied, matter has abnormal conditions superinduced upon it, and is simultaneously influenced by divers forces Endeavours are here made to wrench asunder the molecules of some bodies, to approximate the molecules of others, to curb and restrain intense molecular forces, to augment those which are weak In fact, a laboratory is a torture chamber in which matter is the victim, and the natural philosopher the sworn torturer, the fiery ordeal is a frequent usage, and the voltaic battery extorts confessions with a rack-like vengeance "*Occulta Naturæ*," says Francis Bacon (who, by the way, was the last English judge to use the rack), "*magis se produnt, per vexationes artium, quam cum cursu suo meant*"

Chemical laboratories are more common than physical laboratories In the various European universities, and in many of the larger schools, both kinds of laboratory may be found with lecture rooms attached Perhaps the finest chemical laboratory in the world, is that recently erected in Berlin at a cost of more than £47,000 In a similar institution at Bonn, there are forty-four rooms on the ground floor, including, among others, a large lecture-theatre, a smaller lecture theatre, a chemical and mineralogical museum, a library, special laboratories for fusions and ignitions, gas analysis, and volumetric analysis, and laboratories for students, and for private research A laboratory, to be complete, must be supplied with coal gas, and water, at various pressures, and in pipes of various sizes, with a supply of sulphuretted hydrogen and of oxygen gas, with an extensive supply of reagents, and with apparatus necessary for research or study, that is, with the various appliances by which matter can be submitted to sundry chemical and physical actions It should be light, lofty, well ventilated, and provided with closed cupboards, in which substances which evolve noxious fumes can be heated and experimented with, and through which pass strong currents of air escaping into the chimney A laboratory should have firm and deep foundations, and thick side walls, and it should not be subjected to extremes of temperature Copper should replace iron, as completely as possible, in all internal fittings, such as nails for the flooring, hinges and bolts of doors, &c, in order that magnetic experiments may not be influenced by the presence of iron

The laboratories of the Royal Institution are the most notable in this country In the chemical laboratory Sir Humphry Davy tortured the alkaline bases so successfully that they declared their compound nature, and potassium and sodium became known to chemistry, here too, Faraday discovered benzole, and liquefied many of the gases believed to be permanent In the physical laboratory worked Dr Thomas Young in his endeavours to prove the truth of the now accepted undulatory theory of light, Faraday elaborated his splendid series of electrical researches, and Tyndall is extending our knowledge of radiant actions Natural science has now become so thoroughly a part of the school curriculum, that we are not surprised to find laboratories at some of our larger schools Eton, Rugby, and Harrow possess very good laboratories King's College, London, and the University of Glasgow possess good physical laboratories, which are far more rare in this country than chemical laboratories, but are certainly on the increase Such of the Metropolitan hospitals as have medical schools attached to them, possess a chemical laboratory for students, that at St Bartholomew's is specially noticeable for its size and convenience

LACERTA (The *Lizard*) One of the constellations formed by Hevelius There seems no valid reason why the group of stars forming this constellation should have been abstracted from the constellation Andromeda, to which they originally belonged It is easy to see that the ancients recognised, in this well marked group of stars, the rock to which the hands of Andromeda were chained Lacerta is one of the names which will undoubtedly be removed from our maps if ever astronomy makes an effort to free charts from the complexities which now disfigure them

LACTIC ACID An acid existing in sour milk, and also obtained by fermentation and otherwise It is a colourless syrupy liquid, inodorous and intensely acid Composition is $C_3H_6O_3$ It forms a well crystallised series of salts with bases

LÆVOGYRATE AND DEXTROGYRATE (*Lævus*, left, *dexter*, right; *gyro*, to turn) See *Right handed and Left handed Polarisation*

LÆVOTARTARIC ACID See *Tartaric Acid*

LÆVULOSE See *Sugar*

LAMP, DOBEREINER'S In Dobereiner's lamp, whose object is the production of an instantaneous flame, advantage is taken of the power which *spongy platinum*, that is, platinum in a very finely divided condition, has of condensing gases at its surface, and thus producing an intense heat Spongy platinum may be obtained by heating very strongly the double chloride of platinum and ammonium ($Pt\ Cl_4 2H_4NCl$), whereby a mass of black powder, which is metallic platinum, is left, the remainder being volatilised, and the property referred to is this, that if a jet of hydrogen, mixed with oxygen, be allowed to fall upon a small pellet of the powder, the gases are condensed at its surface rapidly, so as to give rise to heat so great that the hydrogen takes fire

The following is the construction of Dobereiner's lamp A glass vessel 5 or 6 inches high, is three-quarters filled with dilute sulphuric acid, and a second vessel, shaped like a diving bell dips, mouth downward, two or more inches below the surface of the liquid Within the diving bell is suspended a lump of zinc, by means of which and the sulphuric acid, hydrogen is produced, and the gas as it is generated forces the liquid downwards by its pressure so that when the bell is full, the action of the acid on the zinc ceases But if the gas be drawn off the liquid again rises, comes in contact with the zinc and sets up fresh action. At the top of the bell

there is a small tube with a stop-cock, and when the cock is opened, the gas issues from the tube, it is arranged to fall upon a mass of spongy platinum at a short distance from the nozzle of the tube, and this, as we have explained, becomes heated and sets fire to the gas. Thus a flame is always obtainable at will.

LAMP, ELECTRIC. An apparatus in which the intensely brilliant light obtained from the voltaic arc is made use of as an illuminator. It is much used for the display of optical experiments, for lecture illustration, and for such purposes, and has also, to some extent, been employed with success for the illumination of lighthouses. In the latter case, the current of electricity necessary is obtained from a magneto electric machine worked by a steam-engine, and it appears that the expense of fuel necessary is not greater than that of the oil which would otherwise be burned, while the light is much greater and better. As is explained (see *Light, Electric*), when a current is caused to pass between two points of carbon, separated by a small interval, an extremely brilliant, pure, white light is obtained, owing to the heat produced at the carbon points. The tips of the carbon attain an intense white heat, and, at the same time, small incandescent particles are carried bodily between the poles, part of which are burned, and the rest transported from one pole to the other. While it is going on there is, owing to the burning of the particles, a constant wasting of the carbons, and when the interval between the points becomes so great that the current can no longer pass, the light, of course, ceases altogether, and is not renewed till the points are again brought in contact, and then separated once more. The object in the electric lamp is to make a self acting arrangement, which shall always keep the points at such a distance as to give the greatest brightness, and still not allow them to get so far apart by burning away that the current ceases to pass. This is by no means an easy matter, for the greater part of the wasting away takes place in the carbon attached to the positive pole of the battery, and their wasting depends, to a certain extent, on the goodness or badness of the carbon. Hence the electric light is very frequently unsteady, and even if it be steady, it is difficult to keep the bright point in the same position, with regard to lenses or other optical apparatus that may be in use.

The best method of maintaining a constant light is perhaps that of Duboscq, in which the carbon points are constantly moved nearer to each other by means of clockwork. The positive carbon proceeds at double the rate of the negative carbon, by means of a rack movement with unequal wheels. The points are thus constantly urged forward, and would touch each other were it not for the following arrangement:—The current, on passing between the points, enters a coil, in the core of which is a soft iron bar, which thus becomes a temporary magnet. It attracts a keeper, and to the keeper is attached a pin, which locks into a ratchet wheel, and stops the clockwork. The points are then stationary as long as the current is passing, but as soon as the distance between the points becomes so great that the current can no longer pass, the iron ceases to be a magnet, the keeper is let off, and the clockwork, again thrown into action, the points then move up a short distance. Again the current passes, the keeper is attracted, and the clockwork locked, and these actions occur so rapidly in a good apparatus, and with a good battery, that the light is kept sensibly uniform. The light is generally placed within a lantern, furnished with lenses and openings of different forms suitable for optical experiments.

LAMP, MONOCHROMATIC. See *Monochromatic Lamp*.

LAMP, SAFETY. A lamp devised by Sir Humphry Davy, as a result of a long series of investigations into the nature and communication of flame, which will burn and give light in the explosive atmosphere of a coal mine, without setting fire to the explosive gas surrounding it. Sir H. Davy's researches had shown him that the flame of an explosive mixture of gas and air would not pass through long narrow tubes. Upon diminishing the length, and increasing the number of the tubes, the flame still refused to pass, until he ultimately found that wire gauze was sufficient to prevent the explosion communicating from one side to the other. He therefore surrounded an oil lamp with fine wire gauze, and found that sufficient light came through the gauze to enable the miner to work by, whilst the flame was unable to communicate ignition to the explosive fire damp in which it might happen to be immersed in the galleries of a coal mine. Many improvements in detail have since been made, but the principle of the safety-lamp now in use is the same as that of the one first made by Davy.

LAMP, VOLTA'S ELECTRIC. An instrument in which a jet of hydrogen is kindled by an electric spark. It consists of two parts—one, an apparatus for generating hydrogen from sulphuric acid and zinc, in which an arrangement is made for removing the acid from contact with the zinc, by the pressure of the hydrogen itself, as the gas is generated. Thus, a reservoir of hydrogen is filled, and then the action ceases. To the reservoir is attached a stopcock, by which the hydrogen can be allowed to jet out, and the handle which turns the stopcock lifts, at the same time, by means of a wire, the top plate of an electrophorus. A spark is brought

by this wire to pass in front of the hydrogen, which has begun to issue, and which is thus ignited

LAMINABILITY (*Lamina*, a thin plate) See *Malleability*

LANE'S DISCHARGER, (ELECTRIC) See *Discharger, Universal*

LANTHANUM (λανθανειν, to lie hid) A metallic element occurring with cerium and didymium, and deriving its name from its having been hidden in oxide of cerium, which was originally supposed to be the oxide of a single metal It was discovered by Mosander in 1839, and in 1841 he showed that his lanthanum of 1839 contained another metal, which he called didymium (or the *twin*) The separation of oxides of lanthanum and didymium is exceedingly difficult The atomic weight of lanthanum is 92, and its symbol La When pure, its salts are quite colourless, but a trace of didymium imparts a rose tinge to them Metallic lanthanum is a soft malleable white metal tolerably permanent in the air, it forms a *protoxide* (La O) which uniting with acids, forms colourless crystallisable salts, which are, for the most part, soluble in water Lanthanum also unites with chlorine and the elements of that group

LAPIS INFERNALIS See *Nitrates, Nitrate of Silver*

LARMES BATAVIQUES See *Prince Rupert's Drops*

LATHE A machine for turning wood, ivory, or metals It consists of two parallel shafts, the lower one of which forms the axle of a large wheel, and is bent at one point into a crank, so as to be turned by a treadle, the upper one forms the axis of a small wheel termed a *mandrel* A cord passes round the large wheel or mandrel, so that the rotation of the former produces a rapid motion in the latter The end of the mandrel spindle has a screw for holding the material to be turned Before the screw is a platform or rest on which the cutting tool is placed The mandrel is usually compound, being formed of three or more grooved wheels of different sizes One revolution of the large wheel will produce as many revolutions of the small wheel as the circumference of the former contains that of the latter, or as the diameter of the first contains the diameter of the second, hence when a very rapid motion is required the smallest wheel of the mandrel is used When the treadle is worked the tool which is pressed against the body, and held firmly on the rest, cuts out a circle, and by varying the position of the tool, the material is reduced to the required shape The lathe is a very ancient instrument Diodorus Siculus mentions it as an invention of Talus, Pliny ascribes it to Theodorus of Samos, and mentions one Thericles as having rendered himself famous by his dexterity in managing the lathe

LATENT HEAT (*Lateo*, to lie hid) When substances pass from the solid to the liquid condition, and from the liquid to the gaseous condition, they absorb heat A liquid is a solid *plus* heat, a gas is a liquid *plus* heat The heat thus absorbed does not appear as sensible heat, but is consumed in conferring potential energy upon the molecules It thus ceases to exist as heat, and by the older writers it was considered to be hidden in the substance to which it was communicated, and hence received the name of *latent heat* Latent heat was discovered by Dr Black, of Edinburgh, in 1760, the term is still generally retained in science, although the significance of it, as Black understood it, has passed away

If we take a block of ice possessing a temperature of, say − 20° C, insert within it a thermometer, and then communicate heat to the ice, we shall observe that the temperature will rise to 0° C, which is the melting point of ice, and will remain stationary until the last particle of ice has been melted Ice at 0° C becomes converted into water at 0° C, and the whole of the communicated heat has been absorbed in changing the condition of the substance This is called the *latent heat of liquefaction*, and water at 0° C may be described as ice at 0° C *plus* the latent heat of liquefaction This heat has been consumed in overcoming the attraction of the molecules of ice, and in causing them to assume different relative positions In order to liquefy ice an amount of heat is requisite sufficient to raise an equal weight of water through 79 25° C (or 142 65° F) or otherwise expressed to raise 79 25 times that weight of water through 1° C This is the latent heat of water, and it has been variously estimated, according to Lavoisier and Laplace, it is 135° F, Dr Black estimated it at 140° F, Cavendish at 150° F, and De la Prevostaye and Desains at 142 65° F, it may be safely taken as between 142° and 143° F If a pound of ice cold water (32° F) is mixed with a pound of boiling water (212° F) the temperature of the resulting mixture will be 122° F, which is the mean of the two temperatures ($\frac{32+212}{2}$° F = 122° F) But if, on the other hand, a pound of ice at 32° F. is mixed with a pound of boiling water, the temperature of the resulting mixture will be 51° F, but the ice will be melted In the one instance we have two pounds of water at 122° F, in the other two pounds of water at 51° F Now 122° − 51 = 71° F, hence the absolute difference in the amount of heat is that competent to raise two pounds of water through 71° F or one pound through 142° F, and this has been consumed in liquefying the pound of ice This experiment may be modified by placing a pound of ice at 32° F. in a pound of water at 174 65° F,

when the ice will be melted, and the temperature of the resulting mixture will be 32° F Black first endeavoured to determine the latent heat of water, by placing ice at 32° F and water at 32° F in an atmosphere of the same temperature, and noticing the gain of heat by each The water and ice were placed in precisely similar vessels, suspended in a room the temperature of which was 64° F , in half an hour the water had gained 7 2° F , while the ice had not melted, and it did not attain the same temperature before the lapse of 10½ hours, although the gain of heat by each vessel must obviously have been the same throughout Hence the ice had required 10 5 × 2 = 21 times as much heat to melt it and raise it to 7 2° F , as was necessary to raise the same weight of ice cold water to 7 2° F , and the total quantity of heat imparted to the ice was therefore 21 × 7 2 = 151 2°, 7 2° of which had been employed in raising the temperature, and 144° in fusing the ice

The latent heat of liquefaction varies with the nature of the substance , all solids which can be liquefied by heat behave like ice , thus if lead is heated the temperature of the mass will rise until it attains 594° F , when the lead will commence to fuse, and the temperature will remain constant until every particle is fused The *latent heat of fusion* is an expression sometimes used to denote the heat thus absorbed, simply because *liquefaction* is generally applied to solids which ordinarily exist in the liquid form, and *fusion* to solids which usually exist in the solid form, and require a greater or less elevation of temperature before they change their condition M Person has determined the latent heat of fusion of the substances contained in the following table, given by Lardner The unit expressing the latent heat is the amount of heat competent to raise the same weight of water from 32° to 33° F

Names of Substances	Fusing points	Latent heat for unit of weight	Names of Substances	Fusing points	Latent heat for unit of weight
Chloride of calcium,	83 3° F	82 4°	Tin,	455 0°	25 71
Phosphate of soda,	97 5	98 37	Bismuth	518 0	[illegible]
Phosphorus,	111 6	8 48	Nitrate of soda,	590 9	113 36
Bees wax,	143 6	78 32	Lead,	629 6	9 67
Sulphur,	239 0	16 51	Zinc,	793 4	49 43

Let us next consider the *latent heat of vaporisation* When water is heated it rises in temperature until it attains the boiling point (100° C or 212° F) On continuing to heat it there is no further rise of temperature, but the water is converted into water gas or steam The heat, which is absorbed, is entirely consumed in separating the molecules of water against their own attraction, and the pressure of the superincumbent atmosphere The heat thus absorbed is called the latent heat of vaporisation, and steam at 100° C may be described as water at 100° C *plus* the latent heat of vaporisation In order to convert a given weight of water at 100° C into steam at 100° C an amount of heat is requisite sufficient to raise an equal weight of water through 537 2° C (or 967° F), or 537 2 times that weight of water through 1° C This is called the *latent heat of steam* Any given weight of water existing as steam at 100° C , therefore, contains as much latent heat as would raise 5 37 times its own weight of water from the freezing to the boiling point This may be roughly shown by the following means Suppose we have a vessel containing water at 0° C , and that we heat it by some perfectly uniform source of heat, and note the time at which the water commences to boil, and the time at which it is entirely converted into steam, it will now be found that if the time necessary to raise the water from the freezing to the boiling point be represented by 1 , the time necessary to convert it from water at 100° C into steam at 100° C will be 5 3 times as great

Now, the heat which is rendered latent by liquefaction reappears again on solidification , and the heat which was rendered latent by vaporisation reappears again on liquefaction Heat must be abstracted from water before it becomes ice, and from steam before it can become water The heat which is given out on solidification may be made very apparent by saturated solutions of salts If we supersaturate water with sulphate of soda, and allow the solution to cool in a perfectly still place and in a closed vessel, the solid is not deposited , but on agitating the vessel, or introducing a crystal of the sulphate, solidification at once commences, and the latent heat, absorbed during the liquefaction of the solid sulphate, is given out, and is quite perceptible to the touch By using saturated solutions of acetate of soda, Mr Tomlinson has found a rise of temperature of no less than 67° F on the solidification of the substance

The mechanical value of latent heat is very considerable Tyndall has calculated the actual amount of work represented by the changes which water undergoes —First, when 8 lbs of oxygen combine with 1 lb. of hydrogen to form 9 lbs of steam , secondly, when the 9 lbs. of

steam give up their latent heat and become 9 lbs of water, thirdly, when the 9 lbs of water give up their latent heat and become 9 lbs of ice. The first he reckons as mechanical work equal to the raising of 47,000,000 pounds one foot high, the rest we will give in his own words —"After combination, the substance is in a state of vapour, which sinks to 100° C, and afterwards condenses to water. In the first instance, the atoms fall together to form the compound, in the next instant the molecules of the compound fall together to form a liquid. The mechanical value of this act is also easily calculated. 9 lbs of steam, in falling to water generate an amount of heat sufficient to raise 537.2 × 9 = 4,835 lbs of water 1° C, or 967 × 9 = 8,703 lbs 1° F. Multiplying the former number by 1390, or the latter by 772, we have, in round numbers, a product of 6,720,000 foot pounds, as the mechanical value of the mere act of condensation. The next great fall is from the state of liquid to that of ice, and the mechanical value of this act is equal to 993,564 pounds. Thus our 9 pounds of water, at its origin and during its progress, falls down three great precipices. the first fall is equivalent in energy to the descent of a ton weight down a precipice 22,320 feet high, the second fall is equal to that of a ton down a precipice 2,900 feet high, and the third is equal to the fall of a ton down a precipice 433 feet high. I have seen the wild stone avalanches of the Alps, which smoke and thunder down the declivities with a vehemence almost sufficient to stun the observer. I have also seen snow-flakes descending so softly as not to hurt the fragile spangles of which they were composed, yet to produce, from aqueous vapour, a quantity, which a child could carry of that tender material, demands an exertion of energy competent to gather up the shattered blocks of the largest stone avalanche I have ever seen and pitch them to twice the height from which they fell."—*Heat, a Mode of Motion.* (See also *Specific Heat, Internal Work of a Mass of Matter.*)

LATERAL SHOCK. A name given to an effect of electrostatic induction, whereby a shock is experienced by a person standing near where a powerfully charged battery of Leyden jars is discharged.

LATITUDE. (*Latitudo*, breadth.) In astronomy the term latitude is used in two different senses. The latitude of a star or planet is its distance from the ecliptic, measured on the arc of a great circle passing through the poles of that circle. But the most important use of the term latitude in astronomy is that which has reference to terrestrial or geographical latitude, the observations for determining the latitude of a place on the earth's surface entering largely into the work of the astronomer. The terrestrial latitude of a station is the distance of a place from the equator, measured by the angle which the horizon plane of the place makes with the earth's axis, or (which is the same thing) by the real elevation of that pole of the heavens which is visible at the place.

The latitude of a place is determined in several ways by the astronomer.

First, by observing the elevation of the pole star, corrected for the effects due to the motion of this star around the real pole of the heavens.

Again, the latitude of a place may be determined by observing the elevation of any known star when on the meridian, for we have only to add the observed meridional elevation to the north polar distance of the star (which is known), and to deduct the sum from 180°, in order to learn the elevation of the pole,—that is, the latitude.

Thirdly, the latitude may be determined by observing the meridional altitude of circumpolar stars above and below the pole, the mean of these altitudes being obviously the altitude of the pole,—that is, the latitude.

Fourthly, an extra meridional observation of a star's altitude at a known hour gives the means of determining the latitude, because, knowing (1) the polar distance of the star, (2) the zenith distance at the time, and (3) the hour angle, spherical trigonometry shows us how to determine the remaining elements of the spherical triangle having the star, the zenith, and the pole of the heavens at its angular points. One of these elements is the zenith-distance of the pole, or the co latitude.

Fifthly, the latitude can be determined by observations of a star's altitude when on the prime vertical, the results being more exact if the observation is made with a carefully oriented portable transit instrument, the star being observed both during its eastern and western passages of the prime vertical.

Another method, called Sumner's, depends on altitude observations made at intervals of an hour or two.

In all these methods, each observation must be carefully corrected for atmospheric refraction, &c.

Lastly, the latitude of a station may be found by observing the meridian altitude of the sun at the time of the winter or summer solstice, and adding or subtracting the obliquity of the ecliptic to obtain the sun's meridian altitude at an equinox. This altitude is clearly equal to the co-latitude of the place.

LATERAL PRESSURE OF LIQUIDS It is clear that, since liquids transmit pressure equally in all directions (see *Pressure through Liquids*), if we examine the pressure on a very small unit of surface at the edge of the base of a vessel containing liquid, and that on the neighbouring unit of surface on the side, these pressures must be equal, and each equal to the weight of the column of liquid, having for base the unit of surface, and for height the depth of the liquid If we draw an imaginary plane through the liquid, horizontally, at any depth, it is manifest that the liquid beneath this plane acts towards the liquid above it precisely like a rigid bottom receiving pressure from above, and resisting that pressure by dint of the support it receives from below Accordingly, every unit of surface of such a plane, and, therefore, one at the edge is pressed by a column of liquid reaching from the plane to the upper surface, so, also, is the neighbouring unit of surface on the vessel's side Since the weight of such columns vary directly with their height, it follows that the pressure on a unit of surface of the side of a vessel varies with the depth of that unit from the surface, such pressure being nothing at the surface, the weight of a column equal to the vessel's depth, at the bottom, half this half way down, and so on Dykes and embankments which have to resist the pressure of masses of deep water have accordingly to be made thicker towards the bottom

LAW OF EXCHANGES See *Exchanges, Law of* and *Spectrum Analysis*

LAWS OF FRICTION 1 When the materials composing the surfaces in contact remain the same, the friction is proportional to the pressure 2 Friction is independent of the extent of the surfaces in contact 3 When the body is in motion, the friction is independent of the velocity (See *Friction*)

LAWS OF MOTION Three mechanical maxims which were embodied by Newton in three formularies, and termed by him the Laws of Motion They have attained great celebrity in the history of mechanical science, and although they have lost much of their importance in consequence of the more general diffusion of the principles of the inductive sciences, yet they are entitled to notice, together with illustrations of the kind of evidence on which their truth depends

Law I *Every body continues in its state of rest, or of uniform speed in a straight line, except in so far as it may be compelled by impressed forces to change that state*

If a stone be projected along a level road, the speed with which it leaves the hand will not be maintained, but will be gradually diminished, until finally the stone will stop in its course If, instead of the road, the frozen surface of a lake be chosen, the same stone thrown with the same force will travel much farther on the ice than on the road And if, instead of the angular stone, we roll a smooth ball of ivory on the ice, the distance traversed will be greater still It is evident, therefore, that the stone is gradually stopped by the resistances it encounters Similarly, whenever a body ceases to move, it does so because its motion is destroyed by the resistances it meets with The more we diminish these resistances, the longer and the farther will the body move, and, consequently, if we imagine that they are all suppressed, we shall be led to the conclusion that the body under these circumstances would continue to move for an indefinite length of time, in other words, that a body cannot of itself alter its speed, nor can it change the direction of its motion If no obstacle be encountered in its course, the ivory ball thrown on the ice will turn neither to the right nor the left It is true that a stone thrown into the air returns to the ground, but this is because its weight tends constantly to bring it to the earth Conceive the weight and the resistance of the air removed, and the stone will continue to move in a straight line with uniform speed

Thus it is evident that when a body is not acted upon by any external agent, if it be at rest it will remain so, and if it be in motion it will continue to move in the same straight line with uniform speed

Law II *Change of motion is proportional to the impressed force, and takes place in the direction of the straight line in which the force acts*

When a person is on board a boat which is moving uniformly along a stream, any movement he makes produces exactly the same effect as if the boat were at rest When a stone is let fall from a point on land it falls in the direction of the vertical, and when a stone is let fall from the mast of a ship in motion, it reaches the deck at the point vertically below the starting point Now the stone falls from the mast to the deck in the same time whether the vessel be at rest or in motion, again, if the vessel passes horizontally through any distance, three feet suppose, during the fall the stone also passes through three feet horizontally—that is, through the same space as it would have passed through had it remained at the top of the mast We conclude, therefore, that the horizontal motion due to the velocity of the vessel, and the vertical motion due to the attraction of the earth, have each their full effect in their own direction—that is to say, in the resultant motion the stone is displaced horizontally in a certain time,

exactly as if its vertical motion did not exist, and it is displaced vertically in the same time as if its horizontal motion did not exist

On the First and the Second Laws the theory of the motion of the heavenly bodies is based, and the uniform agreement of the deductions from these laws and observations in astronomy is one of the strongest confirmations of their truth

Law III *To every action there is always an equal and contrary reaction, or the mutual actions of any two bodies are always equal and oppositely directed in the same straight line*

When the pressure of one body produces the motion of another, the first is pressed back by the second with an equal force When the hand presses the table, the hand is pressed by the table with an equal force in the opposite direction When a force drives a ball from a cannon, an equal force acts on the cannon in the opposite direction

The law last enunciated is Newton's Third Law, it is usual now to give as the Third Law the following principle which is an extension of the Second Law —*When pressure produces motion, the acceleration varies directly as the pressure, and inversely as the mass moved* (See *Mass*, and *Attwood's Machine*)

LEAD A metallic element, atomic weight 207, symbol Pb, from its Latin name *Plumbum* It was known to the ancients, and very rarely occurs native, it is of a bluish gray colour, very soft and sectile, and easily rolled out, its tenacity is very slight, rubbed upon paper it leaves a streak A freshly cut surface is very brilliant, but it rapidly tarnishes Lead crystallises in octahedrons, its specific gravity in the pure state is 11 44, it melts at about 325° C (617° F), and volatilises at a red heat, when melted it rapidly oxidises, the oxide forming a yellow powdery coating, at a higher temperature the oxide melts and protects the metallic surface from further action Lead is easily reduced to the metallic state by heating its oxygen compounds with a reducing agent, such as carbon The ores of lead may be divided into oxidised ores and the sulphide, from the latter, or *Galena*, most of the lead of commerce is obtained The oxidised ores are the *carbonate of lead* or *cerussite*, which occurs in white fibrous crystals, the *sulphate of lead* or *Anglesite* which also occurs in crystals, the *phosphate of lead* or *pyromorphite*, which frequently occurs massive, and the *arseniate of lead* These ores are mixed with coal or coke and a suitable substance to form a flux with the gangue, and the whole is then heated either in reverberatory or cupola furnaces, when reduction speedily takes place, and the melted metal runs from the tap-hole Galena is reduced by roasting the ore in a reverberatory furnace until it becomes partially converted into oxide or sulphate The admission of air is then stopped, and the partially roasted ore is heated more strongly, when the absorbed oxygen reacts upon the remaining sulphur and forms sulphurous acid, the lead flowing off in the metallic state In this state the lead is not pure, but requires refining Amongst the other metals present, the most important is silver, which, owing to its great commercial value, is always separated as completely as possible, by a process known as Pattinson's process, or the desilverisation process

Pattinson's desilverisation process depends upon the very simple fact that lead containing silver solidifies after melting at a lower temperature than pure lead, and that when the melted lead cools, the portions which solidify first contain more silver than the portion which remains liquid The operation is carried on somewhat in the following manner A row of about ten large iron cauldrons, each capable of holding several tons of lead, is arranged with furnaces beneath One near the middle is filled with melted lead, which is then allowed to cool gradually, being constantly stirred with a perforated ladle, the crystals which first separate are ladled out and transferred to the next pot, on the right, whilst the portion which remains liquid longest is transferred to the pot on the left, in this manner a rough separation of the lead is effected into a richer and a poorer portion Fresh lead is then added to the centre pot, and the operation is repeated, as the pans on the right and left get filled other workmen are occupied in the same manner with them, ladling out the argentiferous crystals to the right, and the poor liquid lead to the left In this manner all the pans get filled, and workmen being in front of each there is a constant circulation of argentiferous lead to the right, and of poor lead to the left, the end pan to the right ultimately getting all the silver, and the end pan to the left getting the desilverised lead In this manner, a lead which did not originally contain more than a few ounces of silver to the ton becomes enriched up to 200 or 300 ounces to the ton

rated from this rich lead by the process of *cupellation* (which see)

Oxides of Lead The principal oxides of lead are the following —

low or reddish crystalline, scaly mass, of specific gravity 9 3, melting at a red heat to a

liquid, it dissolves in acids forming salts, which are usually very crystalline, for a description of the most important, see the respective acids Protoxide of lead is soluble to a very slight extent in pure water, but its solubility is diminished by the presence of salts, such as sulphates,

whose acids form an insoluble compound with oxide of lead Caustic alkalies also dissolve it A hydrated oxide of lead may be prepared by precipitation

Red Oxide of Lead (Pb_3O_4), known also as *red lead* or *minium*, is a scarlet crystalline powder of specific gravity from 8 6 to 9 , it is extensively used as a pigment, and in the manufacture of flint glass It acts as a powerful oxidising agent, being reduced by many reducing agents to the state of protoxide This oxide does not form salts

Peroxide of Lead (PbO_2), is a puce brown powder very easily decomposed by bodies capable of uniting with oxygen Some organic substances, indeed, take fire when added to it It forms crystalline compounds with bases, and is on this account sometimes called plumbic acid

Chloride of Lead ($PbCl_2$), a white crystalline body formed when a soluble chloride is mixed with a soluble proto salt of lead It dissolves in 135 parts of cold water , it is more soluble in hot, and crystallises in long needles on cooling It melts below a red heat

LEANING-TOWERS The permanency of leaning towers, of which those at Pisa and Bologna are the most celebrated, depends on the fact that notwithstanding their considerable deviation from the vertical, the vertical through the centre of gravity still falls within the base (See *Centre of Gravity*, *Equilibrium*) The tower of Bologna is 134 feet high, and a plumb-line suspended from the top, from the side on which the inclination exists would touch the earth at 9 feet 2 inches from the base , in the case of the tower of Pisa 315 feet high, the plumb line would touch the ground at 12 feet 4 inches from the base

LEAP YEAR The name given in England to every year in which there are 366 days (See *Bissextile*) The derivation of the term has been disputed , but there seems little reason to doubt that such a year is called leap year because all dates for one year after February 29th fall not as usual on the day of the week next following that on which they had fallen in the preceding year, but on the next day but one

LEIDENFROST'S EXPERIMENT It was observed by Leidenfrost that, if a drop of water is placed on a red-hot surface, it assumes the form of a more or less flattened spheroid, and evaporates without ebullition The spheroid in this condition does not touch the metallic surface, but it floats on a layer of its own vapour, and evaporates rapidly from its exposed surface It is heated mainly by radiation from the hot surface, because conduction is impossible, since the spheroid is not in contact with the hot surface, and the layer of intervening vapour conducts heat very feebly The absorbed heat is almost entirely required for the rapid evaporation which takes place from the liquid This is known as *evaporation in the spheroidal condition* There are numerous examples of this action If a small metallic ball be heated to whiteness, and placed on the surface of water, it floats for a few seconds until the temperature has been lowered to such an extent that the water comes in contact with it, when it instantly cools down and sinks Again, in burning iron in oxygen gas, it may often be noticed that the white hot globules of oxide fall through a layer of one or two inches of water, retaining meanwhile their high temperature, which is proved by the fact that they sometimes fuse themselves into the earthenware dish on which the jar of oxygen stands A ready mode of showing the spheroidal condition is to heat a platinum dish to redness, and then introduce a little water, the latter immediately spreads out, and assumes a more or less star like form, which is in constant motion while it evaporates If the lamp is removed, the temperature of the dish falls, until suddenly a loud hissing is heard, then a cloud of vapour rises, which proves that the spheroid has come in contact with the hot surface, and has entered into momentary and violent ebullition That the spheroid is not in contact with the heated surface has been proved by the fact, that the light of a candle can be seen through the thin layer of vapour which separates the spheroid from the hot surface, while no light could pass through the blackened and opaque spheroid Moreover, nitric acid assumes the spheroidal condition on a plate of hot copper or silver without acting upon it M Boutigny has proved that the temperature of a liquid in the spheroidal state is always below its boiling point The liquid never attains this temperature so long as it is not in contact with the surface A liquid requires that the surface, upon which it assumes the spheroidal condition, should possess a certain temperature, definite for each liquid, and decreasing as the volatility of the liquid increases M Boutigny has placed this temperature in the case of water at 288° F , and in the case of ether at 142° F A solid surface is unnecessary, for one liquid may assume the spheroidal state upon another If liquid sulphurous acid, which boils at 17 6° F , is placed in a white-hot capsule, it assumes the spheroidal condition, and evaporates slowly , if now water is added, it is instantly frozen in the white hot capsule Faraday varied this experiment by freezing mercury in a white-hot crucible, containing a mixture of ether and liquid carbonic acid, which evaporates in the spheroidal condition at a temperature of about – 150° F The formation of a layer of non-conducting vapour between a hot surface and a liquid explains why it is possible to dip the wet hand into molten iron with impunity.

LENS (*Lentis*, the lentil, so called from its shape) A lens is a piece of glass, rock crystal, or other transparent substance, bounded on one side by a polished spherical surface, and on the other by a spherical or plane surface Lenses refract the rays of light which pass through them, either bringing them to a focus, if they are converging lenses, or spreading them out if they are diverging lenses Lenses may be *spherical, double convex, plano-convex, double concave, plano-concave, meniscus*, and *concavo convex*, each of which is described under its separate heading (See also *Achromatic Lens, Aplanatic Lens, Polygonal Lens, Burning Lens, Fresnel's Lens*) Convex lenses, which bring the parallel rays of light to a focus, form an image of any object which is in front of them If the object is removed from the lens one and a half times its focal distance, the image is projected the same distance behind it, and will be of the natural size, if the object is brought nearer, the image will be magnified, and if removed further off the image will be diminished By employing a lens of long focus, and magnifying this image by another lens of short focus, we have the principle of the telescope, and by employing a lens of very short focus, and magnifying the enlarged image which it gives by another short focussed lens, we have the principle of the compound microscope

Parallel rays of light falling on converging lenses are brought to a focus, and if a source of light is placed in the principal focus, the rays, after passing through the lens, are made parallel

LENS BURNING See *Burning Lens*

LENS, ILLUMINATING See *Illuminating Lens*

LENS, PRINCIPAL FOCUS OF The point at which parallel rays of light, passing through a convex lens, converge to a focus Divergent rays passing through such a lens come to a focus beyond the principal focus, and converging rays to a point within the principal focus (See *Focus*)

LENZ'S LAW Considering the induction effects produced by the motion of a wire, through which a current is passing, upon another wire formed into a closed circuit, Lenz was led to give the following law, which is known by his name —"Whenever a relative displacement takes place between a current and a closed circuit in the natural state, the latter is traversed by an induced current, which reacts so as to determine a motion in the opposite direction, or, what comes to the same thing, which is opposite to the current, that would produce the same displacement" Thus, when we diminish the distance between two parallel wires, one of which transmits a current, the other forming a closed circuit, we obtain in the latter an *inverse current*, but we know (see *Electro-Dynamics*) that two parallel currents in opposite directions repel one another

By considering a magnet, as it is according to Ampère's theory, a solenoid traversed by a current in a definite direction, the law of Lenz may be extended to include the cases of currents induced by the motion of a magnet in the vicinity of a closed circuit (See *Induction, Electro Dynamic*, and *Electro-Dynamics*)

LEO (The Lion) A sign of the zodiac The sun enters this sign on about the 22d of July, and leaves it on about the 23d of August The constellation of the same name occupies the zodiacal region, corresponding to the sign Virgo It is one of the finest constellations in the heavens, though it has been deprived by astronomers of several groups of stars originally forming part of the leonine figure The star Gamma Leonis is a fine binary, the components exhibiting well marked colours—the primary orange, the companion green This constellation also contains many remarkable nebulæ, especially where it touches on the constellation Virgo

LEO MINOR (The Lesser Lion) One of the constellations formed by Hevelius for no apparent reason, so far as one can judge, except to please his own fancy The stars forming this constellation might conveniently have been included either within Ursa Major or Leo There are few conspicuous objects in Leo Minor, but to the telescopist the constellation is full of interest, owing to the number of fine double stars and other objects included within its limits

LEPUS (The Hare) One of Ptolemy's southern constellations It is situated under the feet of Orion Many interesting objects are included within this small constellation One of the most remarkable is the variable red star R Leporis

LESLIE'S CUBE. Sir John Leslie, in his varied and elegant experiments on radiant heat, employed hollow cubes of metal, in which water was kept boiling as sources of heat These are known as "Leslie's Cubes," and are often employed when a constant source of non luminous heat is desired They are usually made of blackened tin, and are from 4 to 6 inches in the side, sometimes they are coated with various metals, powders, woollen materials, &c, to show the variation in the radiative power of different substances.

LEUCONE. See *Silicon.*

LEVANTER A violent wind blowing at certain seasons over the eastern parts of the Mediterranean Sea

LEVEL, WATER Since all portions of the surface of a small liquid mass are sensibly in the same horizontal plane (see *Level Surface of Liquids*), it follows that if we take a long horizontal glass tube, and bend both its ends vertically upwards, and fill the whole with so much water that it rises in both the upright ends, the surfaces of the liquid in these two upright ends will be in the same horizontal plane Consequently, if the eye be placed on a level with one of these surfaces, an object seen on a level with the other surface will be in the same horizontal line with both Such is the simplest form of a water level used in levelling for engineering purposes If a graduated rod be placed vertically with one end on the ground, so as to be intersected by the straight line joining the two liquid surfaces in the level, and if the point on the rod be marked as zero, which is at the same height from the ground on which it rests as the level surfaces are from the ground on which they rest, then the difference between the height of the ground on which the staff is placed and that on which the level can be at once determined by looking along the two surfaces and seeing which division of the staff is on the same horizontal line

LEVEL, SPIRIT If a straight cylindrical glass tube, containing spirits of wine, be sealed at both ends, so as to inclue a small bubble of air, the spirit will of course occupy always the lower portion of the tube, the air space or bubble being at the top If the tube be turned into a vertical position, this arrangement is very quickly assumed, but if the tube be nearly horizontal, and be moved so that one or other end is in turn the lowest, the moving force will be much less, while the inertia and friction will remain sensibly the same, consequently the motion of adjustment will be slower Indeed, if the tube were perfectly horizontal, the bubble would rest in indifferent equilibrium at any spot along its upper surface That the instrument may be less sensitive, and that an approximate result may be obtained in a short time, it is usual to employ tubes which are slightly bent—arcs of annuli—and to fasten them upon stands or feet having smooth flat surfaces, containing the chords of the annular arc Spirits of wine are employed instead of water, because it is more facile in its motion (See *Cohesion of Liquids*) A flat surface may be levelled in a horizontal plane by employing the level successively in two directions at right angles to one another, since if any two lines cutting one another are horizontal, the containing plane is horizontal

LEVEL SURFACE OF LIQUIDS The surface of a liquid at rest is a horizontal plane, or rather a portion of the surface of the earth, which is sensibly a sphere of 4000 miles radius From Art *Pressure through Liquids* it is seen that the level of the liquid surface in communicating vessels is horizontal It is, however, clear that the case of a single vessel may be regarded as the extreme case of approximate vessels, so that the same law must be true of the different parts of the same vessel, as is true of different vessels in communication Indeed it is obvious that the shape of the surface of a liquid in a vessel is determined by the weight of the liquid, and that when a liquid whose parts communicate is at rest, its centre of gravity is in the lowest attainable position, when, and only when, the surface is horizontal

LEVER (French, *lever*, to raise, Lat *levare*) A rigid rod moveable about a fixed point, which is called a fulcrum It is a simple machine, in which one force, called the power, is applied to overcome a resistance technically termed the weight There are two conditions which must be fulfilled in order that the machine may be in equilibrium (1) The resultant of the power and the weight must pass through the fulcrum, and, (2) The resistance of the fulcrum must be equal and opposite to the resultant, or, in other words, the fulcrum must be capable of sustaining the pressure brought to bear on it

When the first condition of equilibrium is fulfilled, the power multiplied by its distance from the fulcrum is equal to the weight multiplied by its distance from the fulcrum When this is the case the lever will have no tendency to turn round its axis in one direction or another, and a very slight increase in the power will suffice to raise the weight

The distances from the fulcrum are called respectively the power arm and the weight arm, hence the above condition is fulfilled when the arms are inversely as the intensities of the power and the weight When the weight is raised, it is obvious that the arms describe arcs, whose lengths are inversely as the power to the weight respectively, since arcs are proportional to the radii

Levers are of three kinds —in the first, the fulcrum is between the points of application of the power and the weight, in the second, the weight is applied between the fulcrum and the power, and in the third, the power is between the fulcrum and the weight The common balance, the steelyard, the crowbar, are examples of single levers of the first kind, an oar (the water reacting against the blade, being the fulcrum, the boat the weight moved, and the force exerted by the oarsman the power), a wheelbarrow, a door moving on its hinges, are of the second kind, the treadle of a turning lathe, and the limbs of most animals, are of the third kind, thus the human arm is a lever of the third kind, moved by muscles attached near

the sockets of the bones, which form the fulcrum Of course in all levers of the third kind the power is greater than the weight, and so acts at a mechanical disadvantage, therefore these levers are always used where speed or space is more important than mechanical advantage

It is not necessary that the bar used as a lever should be straight or that its arms should be in the same straight line, and the forces may be either parallel or not parallel, but in all cases when there is equilibrium, the moments of the forces about the fulcrum must be equal, and to ascertain this in bent levers, or when the forces are not parallel, perpendiculars are let fall on the directions of the forces from the fulcrum, and these form the effective arms of the lever

In double levers, two bars are used, united by a joint at their fulcrum Of the first kind, scissors are an example, the weight being the resistance of the substance to be cut, the power being the hand applied to the other end of the levers Of the second kind, nut-crackers are an example, and of the third, tongs, where the power is the hand, placed just below the fulcrum (See *Balance*, *Weighing Machine*, *Steelyard*, *Wheel and Axle*

LEXELL'S COMET A remarkable comet of short period (See *Comets*)

LIBRA (The *Scales*) A sign of the Zodiac The sun enters this sign on about September 23rd, and leaves it on about October 23rd Its first point marks the place of the autumnal equinox The constellation Libra occupies the zodiacal region corresponding to the sign Scorpio There are few conspicuous stars in the constellation

LIBRATION OF THE MOON (*Libratio*, a poising balancing motion) An apparent oscillatory motion of the moon, which enables us to see rather more than half the surface of our satellite The moon's rotation on her axis is uniform, but her orbital motion is not uniform in a single revolution, nor are different revolutions performed in the same time Hence, though her rotation is accomplished in the mean period of a revolution, rotation and revolution are not completed at exactly the same rate Thus the same effect is produced as though the moon, considered with reference to the earth, had a small oscillatory motion of rotation on her axis It follows that two lunes of the moon's surface become visible in turn Their extremities lie on that diameter of the lunar disc which is at right angles to the direction of the moon's motion, so that their greatest breadths lie on the diameter which is in the direction of the moon's motion This is called the *libration in longitude* There is another libration called the *libration in latitude* It is due to the fact that the axis of the moon's rotation is not quite perpendicular to the plane of her orbit Thus two other lunes become visible by turns, whose extremities lie on that diameter of the lunar disc which is in the direction of the moon's motion, so that their greatest breadth lies on the diameter at right angles to the former Owing to the moon's libration, four-sevenths of her surface can be seen, instead of one half only

The moon's *diurnal libration* is a less important libration due to the earth's motion on her axis

LICHTENBERG'S FIGURES (so called from the name of the observer) show a striking difference between positive and negative electricity with regard to the way in which they distribute themselves over the surface of a non conductor Let a glass plate or a smooth plate of shell lac be well dried, and let lines be traced on it with the knob of a jar positively charged, and then with a jar charged negatively And let a mixture of red lead and sulphur be rubbed together in a warm mortar, and then lightly sifted over the plate The sulphur becomes negatively charged, and the red lead positively when they are rubbed together, and the sulphur therefore adheres to the positive lines of the plate, and the red lead to the negative lines On examining the lines it will be found that a peculiar difference exists between the forms in which the powders are distributed, the sulphur is spread around the line in branching tuft like shapes, while the red lead lies in circular and oval shaped spots The same may also be beautifully shown by employing two plates of shell lac similar to those used in the electrophorous, and allowing a few sparks to fall on one from the positive, and on the other from the negative conductor of the machine, on scattering over each a little fire-brick dust, the forms are very well displayed

LIGHT (A S, *leoht*, light, Ger, *licht*, W, *llug*, Goth, *liuhath*, L, *lux*, light, akin to Sans, *lok*, *loch*, to see, to shine, *ruch*, to shine) Light is the agent or force which excites in our eyes the sensation of vision, and thereby enables us to perceive the phenomena of the external world There are two theories of light, one the *emissive* theory, according to which light is supposed to be due to the shooting out from the luminous body of an infinite number of small particles with inconceivable rapidity, and the other the *vibratory* theory, according to which it is supposed to be caused by the undulations or vibrations of a highly elastic medium called the luminiferous ether (See *Vibratory Theory of Light*, *Emissive Theory of Light*) Light moves in straight lines with enormous although measurable velocity (See *Velocity of Light*) It passes through *transparent* bodies, whilst it is arrested by *opaque* bodies, casting shadows When

it falls upon a light opaque body with a rough surface, it is *dispersed* and scattered about in all directions, and when it falls upon a highly polished surface it is *reflected* back, the *angle of reflection* being equal to the *angle of incidence* When it passes obliquely from one transparent medium to another of different density, it is bent out of its course or *refracted*, and at the same time it is *dispersed* into different colours, constituting the *spectrum* When a ray of light just grazes the edge of a dense substance in its path, it is *inflected* When light is reflected from a polished surface at a particular angle, it becomes *polarised*, acquiring new properties , similar phenomena of polarisation are produced when common light is passed through certain crystals which possess the property of *double refraction* Light may be produced by *chemical action*, by *phosphorescence*, by great *heat*, by *crystallisation*, and it issues from celestial bodies, such as the sun and stars, which shine by their own light All the subjects here briefly alluded to are treated of in greater detail under appropriate headings For the principal divisions the student is referred to the following articles —*Aberration*, *Absorption*, *Actinism*, *Chromatics*, *Circular Polarisation*, *Coloured Polarisation*, *Crystals*, *Deflection*, *Depolarisation* *Diffraction* *Dispersion*, *Double R[illegible] C[illegible]* *Emissive Theory*, *Eye*, *Fluorescence*, *Focus*, *Fraunhofer's Lines*, *Geissler's [illegible]*, *I[illegible] Light*, *Index of Refraction*, *Interference*, *Lens*, *Microscope*, *Newton's Rings*, *Optic Axis*, *Phosphorescence*, *Photometry*, *Polarisation of Light*, *Prism*, *Reflection*, *Refraction*, *Sources of Light*, *Spectrum*, *Telescope*, *Undulatory Theory of Light*, *Velocity of Light*

LIGHT, ARTIFICIAL, COMPARATIVE COST OF Dr Frankland, in his lectures on coal gas delivered at the Royal Institution in the spring of 1867, gives the following table of the comparative cost of the light equal to that emitted by 20 sperm candles, each burning for 10 hours at the rate of 120 grains per hour

	s	*d*		*s*	*d*
Wax, .	7	2½	Cannel gas, . . .	0	3
Spermaceti,	6	8	Paraffin, . . .	3	10
Tallow, . .	2	8	Paraffin oil, . . .	0	6
Sperm oil, ...	1	10	Rock oil, . . .	0	7⅓
Coal-gas, . . .	0	4½			

LIGHT, CHEMICAL ACTION OF See *Chemical Action of Light*

LIGHT, CHEMICAL REACTIONS PRODUCED BY See *Chemical Reactions produced by Light*

LIGHT, COMMON A term applied to ordinary light, to distinguish it from light which has been polarised

LIGHT, CORPUSCULAR THEORY OF See *Corpuscular Theory of Light*

LIGHT, DECOMPOSITION OF See *Decomposition of Light*

LIGHT, LIFFUSION OF See *Diffusion of Light*

LIGHT, ELECTRIC See *Electric Light*

LIGHT, HOMOGENEOUS See *Homogeneous Light*

LIGHTHOUSE LENSES See *Polygonal Lens*, and *Fresnel's Lens*

LIGHT, ITS SUPPOSED INFLUENCE ON COMBUSTION It is an article of popular belief that the sun puts out the fire It is said that if the fire be nearly out, and you put a screen before it, or draw down the blind, or close the window shutters, it will immediately begin to revive But it is forgotten that a fire which looks dull or out, in a well lighted room, will appear to be in tolerable condition in the same room when darkened It only requires to be put together to make it burn up, and it might have done so just as well in the light

If light has any influence on combustion, a candle burning in the sunshine ought to give different results as compared with one burning in the shade But in comparing candles of the same make the light is affected both in quantity and economy by a number of small circumstances, such as the warmth of the room, the existence of small currents of air, the extent to which the wick curls over, and so on In testing the quality of gas the standard defined by Act of Parliament is a sperm candle of six to the pound, burning at the rate of 120 grains per hour From such a standard we get the terms "12 candle gas," "14 candle gas," &c , but, as Mr Sugg has pointed out, the wick does not always contain the same number of strands , they are not all twisted to the same degree of hardness , the so called sperm may vary in composition, one candle containing a little more wax than another, or variable quantities of stearine or of paraffin , the candle may have been kept in store a long or a short time , the temperature of the store room may have varied considerably, and the temperature of the room in which it was burnt may have been high or low All these circumstances affect the rate of combustion, irrespective of the action of light, if such action exist (See *Photometry*)

In a series of experiments described by Mr. Tomlinson (Phil. Mag , Sept 1869), the disturb-

ing causes, above detailed, were carefully eliminated Great care was taken to ensure identity of composition and illuminating power in candles of the same name Moreover, sufficient time was allowed to make a fair comparison, currents of air were guarded against as much as possible, and the temperature was nearly the same in the light as in the dark We quote the results of two of the experiments In the first, three hard and three soft candles were burned each during four hours in a dark closet Similar sets of candles taken from one and the same filling were burned during the same time in open daylight, partly in sunlight The average consumption per hour of each candle was as follows —

Sperm in the dark, ...	134 grains
Sperm in the light, ...	141 „
No 2 Composites in the dark, .	133 „
No 2 Composites in the light, ...	140 „

In this experiment the temperature in the light was 72°, and in the dark 71° Besides in the light there was a much greater motion of air than in the dark closet Both these circumstances would operate in producing a larger consumption of candle

In an experiment where the flames were nearly protected from air currents, and the temperatures both in the light and in the dark were nearly equal, the results with No 2 composites were—

In the dark, .	131 grains per hour
In the light, . .	129 „ „

In another experiment the increase of temperature caused by bright sunshine led to more rapid burning, so that if light has any action it is the reverse of that popularly supposed

Mr Tomlinson's conclusion is that the direct light of the sun, or the diffused light of day, has no action on the rate of burning, or in retarding the combustion of a ordinary candle

LIGHT, LOSS OF, BY PASSING THROUGH GLASS SHADES See *Loss of Light by passing through Glass Shades*

LIGHT LOST BY REFLECTION Some light is lost by reflection from the most highly polished metallic surface, the number of reflected rays diminishing as the obliquity of incidence is diminished A polished mirror of speculum metal has been found to reflect 64 per cent of the incident light after being many years in use, and in refracting telescopes light is also lost by reflection from the polished surfaces of the glass It has been calculated that a refracting telescope would have to be 133 73 inches diameter to give as much light as a 4 feet Newtonian, not taking into account the light absorbed by the glass Allowing for this, Dr Robinson (*Phil Trans*, 1869, p 129), calculates that a 33 73 inch object-glass would be equiluminous with a reflector of 37½ inches When light falls on the surface of mercury at an angle of incidence of 78° 5′, only 754 rays out of a thousand are reflected When the reflector is diaphanous, such as a glass plate, more light is reflected from the second than from the first surface, and this proportion is increased by coating the back with some resinous cement, or still better, with metallic amalgam, the vividness of the reflection from the second surface then completely eclipses that from the first, thus, in the common looking glass, the bright images seen in it are reflections from the second or coated surface (Brook's Natural Philosophy, p 585) Taking the incident rays at 1000, M Bouger has found that the number of rays reflected from the surfaces of water and of glass at different angles are as follows —

Angle of Incidence	Water	Glass
85°	501	549
80°	333	412
75°	211	299
40°	22	34
20°	18	25
10°	18	25

(See *Mirror*, *Speculum*)

LIGHTNING The sudden discharge of electricity from the clouds to the earth, or from cloud to cloud There are several kinds of lightning In the first place, there is the zig zag flash, apparently a continuous line of light, bent in two or more places at extremely sharp angles Secondly, there are flashes which light up a large portion of the heavens with a broad diffused light, and which are accompanied with thunder Thirdly, there is that called *sheet lightning* and sometimes *heat lightning*, because it is frequently seen on warm summer nights, which appears in diffused flashes generally faint, and which is not accompanied by thunder And lastly, the name is applied to certain luminous meteors known also as *fire-balls*, concerning which many incredible stories are told.

The duration of the lightning flash is less than the thousandth part of a second. Wheatstone showed this by means of the principle upon which his chronoscope is founded. A wheel, turned so rapidly that when lighted by a permanent light its spokes blended together, when illuminated by a lightning flash appeared perfectly stationary, and not the slightest indication of displacement could be noticed with regard to the spokes. The spokes had not, therefore, distinguishably moved forward during the time the flash lasted. It is entirely due to *persistence of the image upon the retina* that the flash appears to last for a perceptible time. The *fire balls* on the contrary, are said to last for a considerable time, several seconds at least.

The first kind of lightning, namely the zig-zag flash, is frequently seen, though not so commonly as the second and third kinds. What is seen is simply the line in which the spark travels from the cloud to the earth, or from one cloud to another. It is often of very great length, and is generally made up of a number of straight lines of fire, forming with each other one continuous line, and having several acute angles in it. The zig-zag appearance of the line corresponds with what is observed, on a small scale, in taking long sparks from the prime conductor of a good electric machine. The line which the spark follows is that of the least resistance to its passage, and is not as a rule a straight line. Generally the electricity appears to travel from above downwards, but sometimes an apparently upward discharge is seen. The direction which the discharge seems to take depends upon whether the cloud or the earth is electrified positively, and upon the relative conformations of the cloud and of the ground.

In the second class of flash the light, instead of being concentrated to a single line, is spread over large surfaces. Sometimes it appears to illuminate merely the boundaries of the clouds; sometimes the light seems to come out from the midst of the clouds themselves. This kind of lightning is the most frequently seen; probably it is due to the light of a spark which is seen diffused around and reflected, at a time when the line of the spark itself is concealed by a cloud or otherwise.

That which is called *heat* lightning, and which is unaccompanied by thunder, generally consists of pale flashes most frequently near the horizon; often even when there are no definite clouds visible. It has, in many cases, been proved to be due to distant storms too far off for the thunder to be heard, but of which the light of the flashes is reflected on clouds or mists, and reaches us. There appear, however, to be some cases on record in which the light was seen in the zenith, and which could not be accounted for as proceeding from any distant thunder-storm. Such flashes are possibly due to discharges taking place in the atmosphere at very great heights above the earth.

But little seems to be known about the *fire balls*. They are described as falling slowly from the clouds to the earth, the descent occupying ten or more seconds, and are said often to rebound once or twice upon the ground, and afterwards to explode with frightful violence; but if they are of electric origin at all, it would be difficult to account for such properties according to any known electric laws.

The colour of the lightning is generally white, especially in the case of the zig-zag flashes. Lightning of the second class is, however, frequently of a reddish colour, and occasionally blue and violet are perceived in it. The colour probably depends upon the state of the atmosphere, both as to quality and as to pressure. These circumstances, as we know, influence the colour of the sparks obtained from an electric machine.

To account for the formation of lightning is not easy. It is generally supposed that the small particles of aqueous vapour which leave the earth, and which are afterwards condensed to form clouds, are electrified at the time of, possibly in consequence of, the occurrence of vaporisation. These particles carry their electricity away with them, and, when the cloud is formed, unite together, forming little molecules, which, again uniting, form drops, and the drops are thus in a state of considerable electrification. Probably, then, by means of internal discharges, the interior particles relieve themselves, and throw a portion of their electricity into the periphery of the cloud; and when the outside of the cloud has become very powerfully electrified, a discharge takes place towards the earth, or towards an adjacent and oppositely electrified cloud. The external layer of the cloud having thus relieved itself, the little globules of water again begin to discharge into each other, their size all the time increasing, and the electric strain at their external surfaces increasing also; for it is a well-known law that, in an electrified conductor, such as a drop of water charged could be, the electricity is disposed in a fine layer at the exterior. Again, by a series of internal discharges, the periphery of the cloud is charged, and a second flash occurs. Certain electroscopic experiments seem to show that what we have just described actually takes place, and that, for some time previous to the flash, discharges are occurring from part to part within the cloud.

Lightning possesses the same properties as the ordinary electric spark, exhibiting them with a power proportional to the enormous quantity of electricity which is at work in the production

of a flash Thus it heats intensely any conductor not sufficiently good to carry it readily, fusing bell-wires, chains, thin rods of metal, where it passes along them, and producing those molten tubes known as *fulgurites*, when it strikes the earth, and along its path inward It sets combustibles on fire The passage of a flash can also magnetise, demagnetise, or reverse the magnetism of steel, and can produce chemical effects, an example of which is found in the formation of ozone, nitric acid, and nitrate of ammonium in the air Its mechanical effects are shown in the splitting up of trees, stones, &c, when it strikes them The physiological effects are too frequently recognised When lightning strikes an animal it usually kills it There are, however, instances in which death did not ensue Generally the spark passes through the body, tearing and burning it at the place at which it enters and leaves, frequently setting fire to the clothes, and nearly always burning up the hair on all parts of the body When death does not follow the strokes, deafness, loss of sight, dilatation and loss of contractibility of the pupil of the eye are frequently temporarily produced Instances are known, on the other hand, in which weak strokes of lightning have cured some of diseases under which they were previously labouring As to the number of persons killed by lightning, M Arago estimated it in France at sixty nine in the year M Boudin, however, according to a research quoted by De la Rive, showed that between the years of 1835 and 1852, no less than thirteen hundred and eight persons were killed

In the next article we give some information concerning *lightning conductors*, and under the names *Thunder*, *Return Shock*, *St Elmo's Fire*, will be found an account of these concomitants of lightning

LIGHTNING CONDUCTOR The discovery by Franklin of the identity of lightning with electricity led at once to the idea of protection from the electric discharge by means of a pointed rod Questions long existed as to the utility of the lightning conductor, it being affirmed by some that they tend rather to attract the lightning They do, indeed, concentrate upon themselves the inductive action due to an electrified cloud, but no danger can possibly arise from this if they are properly constructed They ought to be pointed at the top, and are frequently made with more than one point, in order to allow the discharge to take place quietly, and without any spark at all The dimensions of a conductor should be pretty large a thin rod offers too much resistance and may sometimes even be melted by the heat produced It must be continuous throughout, as cases have frequently occurred in which the electricity has left the conductor at a place where there has been a break in the line The end of the rod which is of iron, is metallically connected with thick copper strips which are carried into the ground to a considerable depth and ought, if possible, to terminate in water or in a very wet place, in order to make the communication with the earth as complete as possible In the case of conductors for ships, a strip of copper is inlaid the whole length of the mast and arranged so, that on lowering or raising the masts, metallic contact may still be maintained The strips are carried down to the keel and thus communicate with the water It is found necessary to have each mast furnished with a conductor In some cases in which it was thought that a conductor on the mainmast would be a sufficient protection for the whole ship, one of the the other masts has been struck by lightning and destroyed

The function of the lightning conductor is this When a cloud charged with electricity comes over any locality, intense induction takes place between it and the earth, but in particular this inductive action is concentrated on any projections, such as tall steeples or chimneys, this gradually increases till at last the strain upon the air space between becomes too great for it to sustain, and the flash occurs But if the steeple or chimney be overtopped by the lightning conductor, the inductive action is directed towards it, and since it is pointed, the strain upon the particles of air very soon becomes more than they can support, and the discharge takes place It is, however, of the nature of a quiet brush, the electricity flowing gently outward and neutralising that of the cloud, and the flash is in general altogether prevented Even if it should occur, a conductor of sufficient size can easily carry it to the ground, and the building is saved

LIGHTNING FIGURES It is commonly supposed that when a person is struck by lightning while standing under or near a tree, an "exact portrait" of the tree is impressed on the body of the patient Statements of this kind are so numerous that M Baudin in his Treatise on Medical Geography, proposed a new term, namely, *Keraunography* ("to write with thunder") to include these and other figures caused by lightning In 1861 M Poey collected twenty four such cases and supposed them to be due to a real photo-electric action

It was shown by Mr Tomlinson, at the meeting of the British Association at Manchester in 1861, that a ramified figure, very much like a tree, is really produced with every stroke of lightning, and with every discharge of a Leyden jar If a thin sheet of window glass, about 4 inches square, be held between the knob of a charged jar, and the discharging rod, the discharge will

pass over the surface nearest the jar, turn over its edge, and so get to the discharging rod On holding the glass up to the light no trace of the discharge will be seen, but on breathing upon the glass we get a ramified figure, consisting of a trunk, from which proceed a number of branches covered with spray, the whole figure strongly resembling a tree In some cases the discharge bifurcates, and even trifurcates, in which case there are two or three trunks, each accompanied by its own branches and spray Should the glass be too thick, the charge may not pass, but we get some of its minor details, such as the branches and the spray, representing, in fact, those ramifying feelers sent out by the electricity to prepare the line of least resistance along which the principal discharge takes place These are the lines which produce the sensation of cobwebs drawn over the face, which sailors describe as the forerunners of the ship being struck In the experiment just named the discharge burns away portions of the organic film which covers all bodies exposed to the air, and the breath condenses in continuous streams on the portion so burnt and rendered chemically clean, while on the other parts of the glass the breath condenses in minute globules (See *Breath Figures*) If the glass does not act well in consequence of the irregularity of the film, it may be dipped into a strong solution of soap in water and rubbed dry with a cloth This will give it a continuous film capable of producing remarkably fine figures, the structure of which is worth studying The main trunk of each figure is hollow like a *Fulgurite*

LIGHTNING, SPECTRUM OF The spectrum of lightning has been examined by Grandeau and Kundt It shows the spectra of incandescent *nitrogen*, *oxygen*, *hydrogen*, and *sodium* (See the spectra of these several substances) The nitrogen spectrum is sometimes of the first order, and sometimes of the second, according to the intensity of the discharge

LIGHT OF GAS, DIMINUTION OF, BY ADMIXTURE OF AIR See *Diminution of Light of Gas by Admixture of Air*

LIGHT, ORDINARY AND EXTRAORDINARY RAY OF See *Ordinary and Extraordinary Ray of Light*

LIGHT, RELATION OF GOLD TO See *Gold, Relation of, to Light*

LIGHT, SOURCES OF The sources of light are very numerous, but they may be reduced to few classes First, the sun, fixed stars, and other celestial bodies which do not shine by reflected or borrowed light, second, light evolved by terrestrial bodies in a state of incandescence, such as candles, lamps, and coal gas, the electric light, Geissler's tubes, third, light evolved by phosphorescence, in this class may be included fluorescent light, light evolved during crystallisation, or when certain crystals are broken, and light from glow-worms In this category may also perhaps be included Reichenbach's odic and crystallic light, for although his statements are not generally credited by men of science, a perusal of his original memoirs (Liebig's *Annalen der Chemie*, March and May 1845), will show that he brought to bear on these abstruse subjects as much acuteness of observation and philosophical caution as are generally met with in scientific memoirs

LIMB In astronomy the edge of the sun's, the moon's, or a planet's disc.

LIME See *Calcium, Oxide of*

LIME, CHLORIDE OF See *Chlorine, Hypochlorite*

LIME LIGHT (Also called *Drummond Light*) A very intense light produced by projecting a blowpipe flame of mixed oxygen and hydrogen gases upon a ball of lime The intense heat raises the lime to vivid incandescence When magnesia is used instead of lime it is called the *Magnesia Light*, and when zirconia is employed the *Zirconia Light* Owing to the great explosiveness of a mixture of oxygen and hydrogen gases, special precautions are required *Hemming's jet* is sometimes used, at other times the gases are allowed to bubble through water in their passage from the reservoir to the jet The safest plan, however, is to keep them separate, until they meet at the jet In the *Oxycalcium Light* a jet of oxygen gas is blown through a spirit flame upon a ball of lime When a coal gas flame replaces the spirit flame, it is sometimes called the *Oxy-coal-Gas Light*, the general name for all these lights is the *Oxyhydrogen Light*

LIMIT OF AUDIBLE NOTES The lower limit to the sequence of similar sounds, which produce a musical note, is about 16 complete vibrations in a second At slower rates of sequence the ear can distinguish the separate sounds The higher limit of audible notes varies with different individuals 36,000 vibrations per second give the highest audible note, whose vibrations have been numbered 24,000 is the limit for most ears As the chirp of crickets and the squeak of bats consist of a great number of vibrations, the noise which these creatures make is unheard by many

LINE OF NODES See *Nodes*

LINES OF FORCE, ELECTRIC In an electric field, or field under the influence of a given distribution of electrified bodies, "lines of force," that is, lines the direction of whose

tangent at each point is that of the resultant force at that point, may be drawn upon principles similar to those which are drawn in a magnetic field, and they possess properties analogous to those possessed by the *line of magnetic force* (See next Article, and also *Field, Magnetic*)

LINES OF FORCE, MAGNETIC A line of magnetic force, or simply a line of force (magnetic being understood), is a line which is at each point parallel to the resultant of all the forces at that point "It may be defined," says Faraday, who introduced the term, "as that line which is described by a very small magnetic needle, when it is so moved in either direction correspondent to its length, that the needle is constantly a tangent to the line of motion, or it is that line along which, if a transverse wire be moved in either direction, there is no tendency to the formation of any current in the wire, whilst, if it be moved in any other direction, there is such a tendency, or it is that line which coincides with the magnecrystallic axis of a crystal of bismuth, which is carried in either direction along it" The arrangement of the lines of force about a magnet, or about a number of magnets whose different forces interfere with each other, may be approximately and very beautifully exhibited to the eye by covering them, when laid on a horizontal table, with a tightly stretched screen of white paper, and then scattering fine iron filings over the paper with the assistance of a sieve The filings arrange themselves in curves, which radiate from the poles of the magnet in directions depending on the form of the magnet, and, if there be any magnetic matter in the field, on the position of it with respect to the magnet In the case of a straight bar magnet, evenly magnetised, they start from the poles, and turn inward to meet each other, bending round in oval curves Faraday pointed out another experimental way of recognising and examining the lines of force, both in direction and intensity—namely, by means of a conducting wire moved across them The reader will find a full account of his method and results in the Philosophical Transactions, 1845-1850 Their properties were mathematically discussed by Maxwell, Camb Phil Trans, 1857 (See also *Field, Magnetic*)

LINES OF THE SPECTRUM See *Fraunhofer's Lines*

LINES IN THE SOLAR SPECTRUM, KIRCHHOFF'S THEORY OF See *Kirchhoff's Theory of the Lines in the Solar Spectrum*

LIMITING ANGLE When a ray of light passes obliquely from a dense medium to a rarer one, if the incidence is such that the sine of the refracted ray is equal to the radius of the ray, refraction of the ray becomes impossible and total reflection takes place, below that incidence, however, it is refracted This is called the limiting angle between refraction and reflection The *limiting angle* is found by dividing unity by the index of refraction of the substance (see *Table of Indices of Refraction*), and on looking for the quotient in a table of natural sines the angle corresponding to it is the limiting angle (See *Reflection of Light, Total, Right angle Prism*, also Brooke's *Natural Philosophy*, 1060, Brewster's *Optics*, p 31)

LIQUEFACTION, LATENT HEAT OF See *Latent Heat*

LIQUEFICATION AND SOLIDIFICATION OF GASES Gases and vapours were formerly held to be distinct in their nature, it was Faraday who first proved the distinction to be erroneous by liquefying a number of gases, and since that time all the gases with the exception of six, oxygen, hydrogen, nitrogen, carbonic oxide, nitric oxide, and marsh gas, have been obtained in the liquid condition The general principle upon which the attempts at liquefaction of gases are made is that of applying cold or pressure, or both at once

Faraday's plan was to place in the longer leg of a $\wedge$ shaped glass tube a substance from which the gas could be obtained by heat, (thus to liquefy cyanogen he used cyanide of mercury, for ammonia, chloride of silver, saturated with the gas), and to seal the tube hermetically The shorter limb was then immersed in a freezing mixture and heat was applied to the other In this way a large volume of gas was generated in a small enclosed space, and the pressure upon it rapidly increased as more gas was produced, soon it began to condense into a liquid in the cooled chamber In this way cyanogen, ammonia, chlorine, carbonic acid gas, and others were liquefied, sulphurous acid gas was easily liquefied, it being sufficient to pass it through a tube surrounded by a mixture of snow and salt

Professor Andrews, of Belfast, afterwards constructed a convenient apparatus for the application of cold and pressure at the same time to a gas The gas was contained in a capillary tube sealed at the top, and a small column of mercury in the tube enclosed it below The unsealed extremity of the tube was fastened by secure and water-tight packing into one end of a copper tube, which was completely filled with water, and by screwing a steel screw into the water chamber pressure was obtained, which drove the mercury column up the capillary tube By surrounding the capillary tube with a freezing mixture cold could be applied With this apparatus Andrews was able to subject the gases to the enormous pressure of four hundred atmospheres or more and with the assistance of intense cold from $-106°$ F to $-150°$ F he reduced the gases which we have mentioned above as hitherto uncondensed to, in several cases, less the $\frac{1}{500}$ of the

original volume. Common air was compressed till it had a density nearly equal to that of water, but without showing signs of liquefaction. His paper to the Royal Society, 1861, gives an account of his experiments.

By means of a forcing pump, designed by Natterer of Vienna, carbonic acid is now liquefied on a very large scale in strong iron vessels. The gas is generated in the ordinary way from carbonate of calcium, and passed into caoutchouc bags; it is thence forced into an iron vessel, which is kept cool by the application of ice. If when a considerable quantity of the gas has been condensed, the liquid is permitted to rush out through a small orifice, solidified carbonic acid is obtained in the form of fine white flakes like snow. This is due to the enormously rapid evaporation of the liquid as it escapes. A portion of it turns into gas, and takes up so much heat (see *Latent Heat of Evaporation*), that the remainder of the liquid is frozen to a solid. It was with the assistance of this solid that Faraday was able to study the other gases in their solid and liquid conditions. For on mixing the solid carbonic acid with ether a temperature as low as 106° F below zero was obtained, and by putting the mixture under the receiver of an air pump and rapidly exhausting, so as to assist evaporation, a temperature is obtained which Faraday estimated at 166° below zero. By exposing the liquefied gases in glass tubes to a bath of this kind, he was able to obtain most of them in the form of transparent solids. Afterwards Natterer made use of a mixture of solidified nitrous oxide and bisulphide of carbon, and with the aid of an air pump obtained a temperature as low as 220° F below zero.

The following table, which we quote from Miller's *Elements of Chemistry*, gives the melting points of the solids and the pressures of the gases at the point of liquefaction for various temperatures, according to Faraday's experiments. The pressures are determined by enclosing in the tube in which the liquefaction takes place a small air gauge.

CONDENSATION AND SOLIDIFICATION OF GASES

Names of Gases	Melting point o° F	Pressure in Atmospheres			
		At 0° F	At 32° F	At 60° F	
Sulphurous anhydride,	—105°	0.72	1.53	2.54	5.16 at 100°
Cyanogen,	— 30	1.25	2.37		4.00 at 6[illegible]9
Hydriodic acid,	— 60	2.9	3.97	5.86	
Ammonia,	—103	2.48	4.4	6.90	10.00 at 83°
Sulphuretted hydrogen,	—122	6.7	10.0		14.60 at 52°
Nitrous oxide,	—150	19.3	32.0		33.40 at 35°
Carbonic acid,	— 70	22.8	38.5		
Euchlorin	— 75				
Hydrobromic acid,	—124				
Fluoride of Silicon,	—220				
Arseniuretted hydrogen,		5.21	8.95	13.19	
Olefiant gas,		27.2			26.90 at 0°
Fluoride of Boron,					11.45 —62°
Hydriodic acid,		15.0	26.20		40.0 at 50°

For some further particulars on this interesting subject, and for an account of the most recent and very remarkable researches upon this subject by Dr Andrews, researches which throw a completely new light on the whole subject, we refer to—*Matter, Continuity of the Liquid and Gaseous States of*.

LIQUIDS, CENTRE OF PRESSURE OF. See *Centre of Pressure of Liquids.*

LIQUIDS, COHESION OF. See *Cohesion of Liquids.*

LIQUIDS, COMPRESSIBILITY OF. See *Compressibility of Liquids.*

LIQUIDS, DIFFUSION OF. See *Diffusion of Liquids.*

LIQUIDS, DISPLACEMENT OF. See *Displacement of Liquids.*

LIQUIDS, FLOW OF. See *Flow of Liquids.*

LIQUIDS, INDEX OF REFRACTION OF. See *Refraction, Index of.*

LIQUIDS, LATERAL PRESSURE OF. See *Lateral Pressure of Liquids.*

LIQUIDS, LEVEL SURFACE OF. See *Level Surface of Liquids.*

LIQUIDS, PRESSURE OF, ON THE BOTTOM OF VESSELS. See *Pressure of Liquids on the Bottom of Vessels.*

LIQUIDS, PRESSURE THROUGH. See *Pressure through Liquids.*

LIQUIDS, SPECTRA OF INCANDESCENT. Liquids when incandescent give continuous spectra like solids. (See *Solids, Spectra of Incandescent.*)

LIQUID SURFACES, TENSION OF See *Tension of Liquid Surfaces*

LIQUIDS, UPWARD PRESSURE OF See *Upward Pressure of Liquids*

LIQUIDS, WAVES IN See *Waves in Liquids*

LISSAJOUS' COMPARISON OF TUNING-FORKS In the kaleidophon (see *Kaleidophon*) one and the same body receives impulses in different directions, and it vibrates at different rates in those different directions, the figures which the end describes marks the difference of rate, and also the difference of phase In order to compare sonorous bodies with one another, especially tuning-forks, with a view to test whether a given fork is in perfect unison with the normal diapason, or in any aliquot relation therewith as to its rate of vibration, Lissajous reflected a beam of light from one prong of the standard fork in an upright position upon the prong of the fork which is being tested, fixed in a horizontal position, and thence on to a screen When the forks are in perfect unison, a straight line, circle, or more or less eccentric ellipse will be described on the screen when both forks are in vibration, according to the phases of the vibrations If one of the forks be slightly weighted, these curves will not remain constant Similarly, if the two forks are related as a note and its octave, the figure described is some modification of the figure of 8 In fact, the whole series of phenomena are exactly like those presented by Wheatstone's Kaleidophon, for the conditions which produce them are essentially identical

LITHARGE See *Lead, Oxides.*

LITHIC ACID See *Uric Acid*

LITHIUM A metallic element belonging to the alkali group Atomic weight 7, symbol Li It occurs in very minute quantities, but is somewhat widely spread The metal is silver white, much resembling potassium in its properties, a freshly-cut surface tarnishes very readily It is softer than lead, and may be drawn out into wire, and welded together by pressure at the ordinary temperature It is the lightest known solid, its specific gravity being only 0 578 It melts at 180° C (356° F), and at a much higher temperature burns with a most intense white light When thrown on to water it oxidises rapidly, and floats about, but does not melt or inflame Thrown on to strong nitric acid it takes fire, burning with an intense white light The following are the most important compounds of lithium

Oxide of Lithium (hydrated) (LiHO) is a caustic alkali, similar to caustic potash, soluble in water, and capable of neutralising acids to form salts, which have a great resemblance to the salts of the other alkali metals

Chloride of Lithium (LiCl) This separates from its aqueous solution in crystals, having the appearance and taste of common salt (chloride of sodium) It is readily soluble in water

LITHIUM, SPECTRUM OF The spectrum of a lithium compound, ignited in a spirit flame, consists of one intense crimson line, nearly midway between Fraunhofer's B and C At a little higher temperature, that of a hydrogen flame, for instance, a yellow line makes its appearance, and at a still higher temperature, such as that of the electric arc, a brilliant blue line appears (See *Spectrum Analysis, Spectrum*)

LITMUS A vegetable colouring matter extracted from various species of *Roccella tinctoria*, &c It is coloured blue by alkalies and red by acids, and, on this account, is much used in the preparation of test papers

LOADSTONE (*Lædan*, Sax, to lead) The name given to the magnetic oxide of iron, probably from the property it has of pointing north and south if properly suspended The magnetic oxide of iron is found in many parts of the world,—in Arabia, China, Bengal, Macedonia, Germany, England It is a hard stone, varying in colour from reddish black to deep gray It is composed of iron and oxygen in the proportion of 73 parts of the former to 27 of the latter, its chemical symbol is Fe_3O_4 It was discovered by the Greeks, and probably long before them by the Chinese, that this stone has the power of attracting soft iron, and it has also long been known to be capable of communicating attractive power to a steel bar which is rubbed with it (See *Magnet*)

LONGITUDE (*Longitudo*) In astronomy longitude is used in two different senses The longitude of a star or planet is the angle included between two planes, both passing through the poles of the ecliptic, one through the first point of Aries, and the other through the star or planet It is reckoned from the first point of Aries in the order of the signs from 0° to 360° So far as the stars are concerned, celestial longitude may be regarded as having passed altogether into desuetude As regards the planets, however, it is obviously convenient to retain the use of celestial longitude, since these bodies always lie near the ecliptic along which longitudes are measured (See *Geocentric*, and *Heliocentric*)

But the most important use of the term longitude in astronomy, refers to terrestrial longitude, or the angle between two meridional planes, one passing through a particular station, the other a fixed plane of reference. We may also describe the longitude of a place as the arc of a small

circle, having the poles of the earth as poles, intercepted between the two aforenamed planes; or the arc of the equator intercepted between those planes Longitude is commonly measured east or west of the fixed meridian through 180° That meridian is different for different countries In England the meridian of Greenwich is adopted as the origin whence longitudes are measured In Paris, the meridian of Paris is adopted, in America, the meridian of Washington, and so on

The determination of the longitude of any station on the earth, whether on land or on the ocean, is of the utmost importance to the astronomical observer, the traveller, and the seaman The problem is not an easy one It is not difficult to determine the latitude of any station since there is an actual change in the aspect of the heavens (for every hour) with any change of latitude But in travelling from east to west or from west to east, there is no change in the aspect of the heavens, the stars seen at any moment in one longitude being situated precisely as they would be seen, though not at the same moment, from any other station in the same latitude

All methods of determining the longitude are based on the fact that the apparent time is different for two places separated by any distance in longitude The sun or any given star will cross the celestial meridians of the two places at different hours, and so also any celestial phenomenon will occur at different hours of apparent time On the other hand, the occurrence of any phenomenon indicative of apparent time, as the southing of the sun or a star, will take place at different hours of absolute time

For places on land any method by which the difference of time at two stations can be determined will serve to determine their difference of longitude Formerly the method adopted was to transfer chronometers from one place to the other, repeating the journey backwards and forwards several times in order to eliminate as far as possible the effects due to variation of rate Supposing that at each station the sidereal time is accurately known, it is evident that in this way, the difference between the sidereal times of the two stations can be accurately measured In modern times, telegraphic signals are more commonly employed It is evident that, if signals are sent from one station to the other at the moment when any celestial phenomenon as the transit of a star takes place, the difference of time between the two stations can be accurately determined

Eclipses of Jupiter's satellites afford a rough method of determining the longitude, since they occur at the same moment of absolute time as seen from different parts of the earth If an eclipse or occultation were an instantaneous phenomenon, and visible at the same moment whatever telescopic power was employed, this method would be the best of all As, however, neither of these conditions holds, the method is far from exact Further, the tables of the motions of these satellites at present in use, are not exact enough to give the time of an eclipse or occultation with the necessary approach to accuracy

Occultations of fixed stars by the moon afford another means of determining the longitude Since occultations do not occur at the same instant at different stations, processes of calculation are required to deduce the longitude from observations of occultations

The longitude of a place can also be determined by observations of lunar transits, because the sidereal time of lunar transits is not identical at different stations, and the difference of time serves to supply means for calculating the difference of longitude A form of this method is that known as the "method by *moon culminating stars*" It consists in observing the difference of sidereal time between the transit of a star close to the moon and having nearly the same declination This difference, if exactly determined, gives the true sidereal time of the moon's transit, and therefore, as before, the longitude of the station

For observations to be made at sea other methods must be adopted One method is to observe the altitude of the sun at about that part of the day when his altitude is changing most rapidly This altitude being determined, and the latitude and time of observation known, (the latter from the chronometer), the longitude can be calculated

The method of determining the longitude by lunar distances depends on the same general principle as the lunar methods used on land The Nautical Almanac supplies the lunar distances of certain bright stars, calculated for Greenwich, and by comparing the apparent time when the lunar distance of a star has a given value with the apparent time at Greenwich when the star's lunar distance has that value, the sailor has the means of determining the longitude of his ship

It need hardly be said that in the application of all these methods corrections for atmospheric refraction, &c, must be duly made

LONGITUDE, GEOCENTRIC, OF A HEAVENLY BODY See *Geocentric*

LONGITUDE, HELIOCENTRIC, OF A HEAVENLY BODY See *Heliocentric*

LONGITUDE OF THE PERIHELION. The heliocentric longitude of that point of a

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planet's orbit which is nearest to the sun. It is usually measured upon the ecliptic to the node and thence along the orbit forwards or backwards as the case requires, the sum or difference of the arcs on the ecliptic and orbit being taken as the longitude of the perihelion. But this is not the just method. The only correct mode of exhibiting the position of the perihelion of an orbit is to assign its true heliocentric longitude and latitude.

LONGITUDINAL VIBRATIONS. If a smooth slender cylindrical rod of wood be held at its centre, and one end of it be rubbed in the direction of its length with a piece of wash leather, covered with powdered resin, a musical note is produced which varies with the length and material, and, to a slight extent, with the thickness of the rod. The rod is set into a series of longitudinal vibrations. The centre of the rod remains at rest, and the two extremities are the points in the most violent vibration. The first is a node, the second are the centres of segments. The condition of such a rod is precisely like that of a pipe of air open at both ends, and sounding its fundamental note. (See *Organ Pipes*.) For the same material and thickness the number of vibrations in a given time is inversely as the length. For the same material and equal lengths the number of vibrations increases slightly with the thickness. As the length of the rod is half the wave length, the latter can be at once measured. Since the pitch of the note is the number of vibrations in a given time, by comparing the pitch of two notes produced, one by an open organ pipe, and the other by a longitudinally vibrating rod of the same length as the pipe, or by comparing the lengths of the two when they produce the same note, the velocity of sound can be ascertained as follows.—Suppose we have to use a rod of deal, eight feet in length, to produce the same note as that given by an open organ pipe six inches long. The rate of motion in the two media must be inversely as their lengths, since those lengths are traversed in the same time. Hence the rates are as 1 to 16. Accordingly sound travels through deal at the rate of 17,600 feet per second. The same number is, of course, obtained by multiplying by 1100 (the rate of sound in air), the ratio between the pitches of the notes produced by equal lengths of deal and air.

If a rod, fastened at one end, be set in longitudinal vibration, the fixed end will be a node and the free one the centre of a segment. Such a rod therefore will be represented by an organ pipe closed at one end. Accordingly, as before, the number of vibrations varies directly with the length of the rod. One rod gives the octave above another when it is twice as long. If two rods of the same length and material are fastened, one in its centre, and the other at its extremity, and are set in longitudinal vibration, the one fastened in its centre will sound the octave above the other.

If a wire fastened at both ends be set in longitudinal vibration, each end will be a node, and the middle the centre of a segment.

LONG-SIGHTEDNESS. This imperfection of sight is due to the *crystalline lens* being insufficiently convex, thus causing images of objects to come to a distinct focus, not on the retina but a little behind it. This may be perfectly remedied by assisting the insufficient convexity of the crystalline lens by placing a slightly convex lens in front of the eye. (See *Eye*, *Spectacles*.)

LOOKING-GLASS. See *Mirror*.

LOOMING. A phenomenon of unusual refraction, by which coasts, mountains, and ships on or below the horizon at sea, appear elevated above it, and sometimes inverted. (See *Refraction, Unusual*.)

LOSS OF LIGHT BY PASSING THROUGH GLASS SHADES. As coal gas is almost always surrounded with a glass shade when it is burnt, it is of interest to know the amount of loss occasioned by the passage of light through the substance of which the shade is composed. Dr Letheby gives the following table:—

	Loss Per Cent
Clear glass,	12
Slightly ground in pattern,	24
Half ground,	35
All ground,	40
Opal glass,	60

LOUDNESS OF SOUND. The loudness of one sound, as compared with that of another being a nervous effect, is incapable of mathematical representation. If the intensity of the sound is proportional to the bending of the drum of the ear, then it is also proportional to the amplitude of the vibration of the particles of air. If it is proportional to the strength of blow which the ear receives, then it varies with the square of the amplitude. Two notes of one pitch, but of different degrees of loudness, are sounded at such distances from the ear that they seem equally loud. We find that the amplitude of the vibrations of the two notes at the

ear are equal From the fact that the sound varies in mechanical intensity, inversely as the square of the distance from the source, it is usual to consider the audible intensity as varying directly with the square of the amplitude

LOWE'S PHOTOMETER See *Jet Photometer.*

LUBRICANT (*Lubricus*, smooth, slippery, *lubricans*, making smooth) Any substance applied to make one body glide over another, or to facilitate the motion of bodies in contact, by diminishing friction Viscous liquids are generally used for this purpose, although very finely powdered plumbago has been found useful in diminishing friction between highly polished metallic surfaces of machinery Lubricants reduce friction by filling up the interstices between the particles on the surfaces in contact, and so preventing their interlacement Consequently the more viscous substances are used where the surfaces are rough, and the more fluid between polished surfaces Thus tallow or some viscous grease is used when metal moves upon wood, &c but, in the case of metallic surfaces only, oil is employed, its fineness increasing with the hardness and smoothness of the metal (See *Friction*)

LUMINIFEROUS ETHER See *Ether, Luminiferous*

LUMINOSITY OF FLAME See *Flame, Luminosity of*

LUMINOUS RAY, PENCIL, SHEAF, BEAM, or FASCICULUS These terms are applied almost indiscriminately , they generally refer to the path of a line of light of a definite width and thickness A pencil or beam is supposed to consist of a multitude of rays, which may be parallel, convergent, or divergent

LUNAR, CAUSTIC See *Nitrates , Nitrate of Silver*

LUNAR DISTANCES A method of determining the longitude at sea. (See *Longitude*)

LUNAR THEORY The mathematical analysis of the perturbations to which the motions of the moon are subject

An account of the processes by which mathematicians have mastered, or are mastering, all the peculiarities of the lunar movements, would be wholly out of place in such a treatise as the present We propose, however, to state the general nature of the chief phenomena of lunar motion

For convenience, we may regard the earth as at rest, the moon circulating round her once in a sidereal lunar month, the sun once in a sidereal year Now, since this imagined orbital motion of the sun takes place outside the moon's orbit, it will be obvious that on the whole the action of the sun must tend to draw the moon away from the earth, or, in other words, to diminish the earth's influence over her satellite But it is only on the whole, that is, in considering a complete lunation, that the sun's action is of this nature When the line from the moon to the earth is at right angles to the line from the sun to the earth, the sun evidently acts to increase the moon's tendency towards the earth's centre On the other hand, when the moon, earth, and sun are in the same line, the sun acts to diminish the earth's influence on the moon, for if the moon be beyond the earth he pulls the earth more than the moon, that is, he tends to pull the earth away from the moon, whereas, when the moon is between the earth and the sun, the sun pulls the moon more than the earth, or tends to pull the moon away from the earth in either case then he tends to diminish the force which tends to draw the earth and moon together

The Moon's Annual Equation The action of the sun in diminishing the earth's influence over the moon, taking the balance of effects accruing during a single lunation, will clearly be greater or smaller according as the sun is nearer to, or farther from, the earth Hence during those lunations which occur when the earth is near perihelion, the moon's orbital period will be longer than during those lunations when the earth is near aphelion Hence the winter lunations are longer the summer ones

Further, since in winter the moon thus lags, while in summer she hastens her movements, it is obvious that an equation precisely resembling in character that applied to the sun (see *Equation of the Centre*), has to be applied to the moon's mean motion The greatest amount by which, so far as this cause is considered, she gets in advance of, or falls behind her mean place, is about 10′ This inequality was detected by Tycho Brahe

The Moon's Variation Since the sun acts most strongly to diminish the earth's influence on the moon, when the moon is nearly at new or full, or in *syzygy*, and to increase the earth's influence on the moon when the moon is at her quadratures, we see that so far as this radial influence is concerned, the moon should move most slowly when in *syzygy*, and most swiftly when in quadrature, and therefore there must be acceleration in passing from *syzygy* to quadrature, and retardation in passing from quadrature to syzygy But in considering the moon's motion throughout a complete lunation, another mode of action exerted by the sun has to be considered, viz ; that tangential action which tends to accelerate or retard the moon's motion directly, Now it is to be carefully remembered that it is not the sun's action on the moon alone that is

here in question, but the difference between his actions on the moon and earth. It is very common to see the sun's action on the moon as she passes from full to new (that is, from farther to nearer syzygy), described as accelerative, but in reality it is only in the nearer half of this course that the sun acts acceleratively, and this because his action on the moon exceeds his action on the earth; in the other half, his action tends to retard the moon. Similarly as the moon passes from nearer to farther syzygy, the sun's tangential action retards her motion in the first half, and accelerates her motion in the farther half. It appears then that the radial and tangential forces have contrary effects, so far as the moon's orbital velocity is concerned.

But the tangential force has the greater effect, so that in each lunation the moon's velocity is greatest when she is in syzygy, and least when she is nearly in quadrature. The inequality thus arising is called the moon's *variation*, and its maximum value is 32'. This inequality was also discovered by Tycho Brahe.

The Moon's Parallactic Inequality. If the sun's distance were indefinitely great compared with the moon's, his disturbing influence would be as great when the moon was traversing the half of her orbit which lies farthest from him, as when she was traversing the nearer half. As, however, though the ratio which the sun's distance bears to the moon's is very great, it is yet not infinite, there arises a small inequality due to the fact that the moon's distance from the sun at the time of full moon does not bear to the earth's distance from the sun, a ratio quite equal to that which the earth's distance from the sun bears to the moon's distance from him at the time of new moon. The inequality is small, never exceeding 2', but it is quite recognisable, and has supplied one of the most effective modes of measuring the sun's distance, since clearly its extent depends on the ratio which the sun's distance bears to the moon's.

The changes in the inclination of the moon's orbit, and the position of the nodes, and those in the eccentricity and the position of the perigee, can only be properly dealt with in a set treatise. The reader is referred to Mr Airy's work on Gravitation.

Inequalities depending on the oblateness of the earth's figure, though small, are interesting, as supplying the means of determining the compression of the terrestrial globe. The estimated compression is $\frac{1}{305}$, corresponding very closely with the results which have been obtained by other methods.

The *Acceleration of the Moon's Mean Motion* is described under that heading.

The influence of the planets on the moon is insensible, except in the case of Venus, the peculiar relation of whose period to the earth's (see *Venus*), causes an inequality of long period to affect the lunar motions.

LUNATION. See *Month, Synodical*.

LUNI-SOLAR. Referable to both the sun and moon,—as the luni-solar precession, or the total amount of precession produced by the action of the sun and moon.

LUPUS (The Wolf). One of Ptolemy's southern constellations. It is represented in maps as transfixed by the spear of Centaurus. There appears to have been some doubt amongst ancient astronomers as to the true title of this asterism. They were agreed that it represents some offering which Centaurus is placing on the altar (represented by the stars of Ara), but differed as to what that offering might be. Only a portion of this constellation rises above the horizon of London, and these are seen under unfavourable atmospheric conditions, yet some of them are included in Flamstead's list.

LYNX (The Lynx). One of the constellations formed by Hevelius. It contains few conspicuous stars, but many objects of great interest to the telescopist, a large proportion of its *lucidæ* being double.

LYRA (The Lyre). One of Ptolemy's northern constellations. Though not of great extent, this constellation is a very rich one. The brilliant Vega is its chief orb. The star Beta Lyræ is a remarkable variable. (See *Stars, Variable*.) Between Beta and Gamma is situated the remarkable ring-nebula 57 Messier. This is one of those nebulæ which Mr Huggins has discovered to be gaseous. The whole of Lyra is rich in objects of interest, the number of compound star systems being surprisingly great. Of these, perhaps the most interesting to the telescopist is the quadruple system formed by the two double stars ϵ^1 and ϵ^2 Lyræ. To the naked eye these stars appear as one, though exhibiting a somewhat elongated appearance and even separable by exceptionally acute vision. In a small telescope they are seen as a wide double; and in telescopes of considerable power each component is seen to be a close double. All four stars appear to form one system, since both ϵ^1 and ϵ^2 are recognised binaries, while they are travelling with a common proper motion.

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MACHINE. Any contrivance for transmitting force from one point to another or for increasing or regulating the effect of a given force. The *simple machines* are the *lever*, the *wheel and axle*, the *pulley*, the *inclined plane*, the *screw*, the *wedge*. Compound machines consist of combinations of these simple machines. They admit of infinite variations and adaptations, but there are certain laws found to apply to all machines. The work of a machine is measured by the amount of resistance overcome in a given time. An important empirical law, due to Euler, gives the relation which must subsist between the speed and the resistance in order that the effect may be a maximum. The load or resistance should be about four ninths of that which would exactly counteract the power or keep the machine at rest, and the velocity of the point or points of application of the power should be one-third of their greatest velocity. When these two conditions are fulfilled the machine will work to the greatest possible advantage. Thus a mill will do the greatest amount of work in a given time when the wheel has one third of its greatest possible velocity, and overcomes a resistance equal to four ninths of the greatest resistance against which it can move; an animal will accomplish the greatest amount of work in a given time when it moves with one third of its greatest speed and is loaded with four-ninths of the greatest load it is capable of moving. (Moseley's *Mechanics Applied to the Arts*; Gregory's *Mechanics*; Coriole's *De l'Effet des Machines*.)

MACULÆ (*Spots*). The solar spots. See *Sun*.

MADDER. The root of a plant belonging to the order of *Rubiaceæ*, amongst which are included some valuable plants, such as the cinchona, ipecacuanha, and coffee. The madder plant is the *Rubia Tinctoria*. The value of madder in dyeing and calico printing depends upon the many different colours which can be dyed by its means. Thus an iron mordant gives purple shades from delicate mauve to black; another mordant, alumina, gives red shades, from the palest pink to deep crimson, including the brilliant and well known Turkey red; and, by appropriate admixture of these mordants, varieties of chocolate brown are produced. These colours are all very permanent. The colouring principle of madder is alizarine (which see).

MAGELLANIC CLOUDS. See *Nubeculæ*.

MAGENTA. See *Aniline*.

MAGIC LANTERN. An optical instrument, consisting essentially of a dark box, containing a system of convex lenses attached to one of its sides, and an arrangement for holding transparent pictures a little beyond the *principal focus* of the combination of lenses. A strong light from an oil or gas lamp, the lime light, or electric light, &c., being placed inside the box, and condensed upon the picture, the convex lenses project a magnified image of the picture upon a white screen placed in front.

MAGNESIA. See *Magnesium*.

MAGNESIA LIGHT. See *Lime Light*.

MAGNESITE. See *Carbon, Carbonate of Magnesium*.

MAGNESIUM. A beautiful silver-white metal, much resembling zinc in its chemical properties. Symbol Mg. Atomic weight 24·3. Specific gravity 1·75. It melts at a red heat, and takes fire at about the same temperature in the air, burning with an intensely brilliant white light. A wire or ribbon of magnesium, lighted at one end, will continue to burn like a wax taper, and is in constant use for pyrotechnic and illuminating purposes, especially in photography, owing to its richness in actinic rays. When burning, it evolves dense white clouds of the oxide, magnesia. Magnesium does not tarnish in dry air, but it soon becomes covered with a white coating of oxide in the damp. It only forms one oxide which is

Magnesia (MgO), a light, white, tasteless, and inodorous powder, of specific gravity about 3·1. It is very slightly soluble in water, communicating to it a faint alkaline reaction. It dissolves easily in acids, forming salts of magnesium, which are for the most part easily crystallizable.

Chloride of Magnesium ($MgCl_2$). This is a white crystalline mass of a pearly lustre, melting at a red heat, and readily soluble in water. With increase of temperature the hydrated chloride ($MgCl_2 3H_2O$) crystallises out on evaporation from this solution. When this is heated, water and hydrochloric acid are evolved, and magnesia is left behind. The other salts of magnesium will be described under the respective acids.

MAGNET (From the Greek *μάγνης*). A body which has the property of attracting iron and certain other metals in a particular manner, is called a magnet. There are permanent magnets and temporary magnets. The latter are treated of under the names *Electro-magnet* and *Electro-magnetism*. Of permanent magnets, there are *natural* magnets and *artificial* magnets.

Natural Magnets In Magnesia, a city of Lydia (hence probably $\mu\acute{\alpha}\gamma\nu\eta\varsigma$), a stone was found which, it was well known to the Greeks, had the property of attracting or drawing to itself small masses of iron. The Chinese also, as it appears from ancient manuscripts, were acquainted with this stone, and with certain other properties which it possesses It is now found in many parts of the world, in Arabia, China, India, Macedonia, Germany, Norway, and England It is commonly called *loadstone*, and is known to chemists under the name of magnetic oxide of iron. It consists of iron and oxygen combined together in the proportion of about 73 parts of the former to 27 of the latter, and is designated by the formula F_3O_4 It is a heavy, hard stone, of colour varying from red to brown and black This stone attracts iron, and forms a natural magnet

If a piece of it be rolled in iron filings, it will be found, as a general rule, that the filings adhere more thickly to two points at opposite sides of the mass than to any other parts, and that between these there is a region going round the mass which has comparatively little attractive power These points are commonly called the magnetic *poles*, a line joining them the magnetic *axis*, and the apparently attractionless region the magnetic *equator* Now, if the magnet be suspended so as to be capable of turning in any direction, it is found to take up a peculiar and definite position with regard to the earth In our part of the earth's surface the magnetic axis points *nearly north and south*, the same end of it always pointing northward, and, at the same time, it *dips* downwards towards the north—that is, makes an angle acute towards the north, with the horizontal plane The direction in which the magnetic axis points depends upon the position upon the earth's surface, but at any particular place and time it is fixed and definite A full account of this property is to be found in the proper place

Again, if a piece of *soft* iron be brought near to the magnet, it is attracted, and, at the same time, it acquires the property temporarily of attracting other masses of iron Thus, a piece of soft iron may be suspended from the stone, and to the extremity of that piece another piece may be made to attach itself by attraction, and a third to the second On removing the iron from the influence of the magnet, however, the property of attraction entirely vanishes from it This phenomenon is called *magnetic induction* (See *Induction, Magnetic*) Lastly, if a bar of hard steel be rubbed from end to end with the magnetic stone, it acquires the property permanently of attracting just as does the natural magnet, and hence we come to

Artificial Magnets Under this head we shall describe more particularly the properties of magnets with the preliminary remark, that all we have to say applies equally to the natural magnet, except that, owing to its usually irregular shape, some of these properties do not display themselves so definitely, and are more difficult to examine in it The methods of making artificial magnets are described under *Magnetisation* The best magnets are formed of cast steel, which is made as hard as possible, in the first instance, and afterwards let down to a temper somewhat below that known as "drill temper" Magnets are generally made either in the form of a straight bar, or of a bar bent round into the form of a horse shoe The horse shoe magnet is most convenient for lifting purposes, but for many others the bar magnet is best Compound magnets, formed of a number of plates, each separately magnetised and then attached together, are also frequently used, the magnetic power obtained in this way being greater than in the simple magnet of equal weight As has been remarked, these steel bars on being rubbed with the loadstone, become themselves permanently magnetic, and they also acquire the power of magnetising other bars by making a large number of weak magnets, and afterwards using them in bundles to magnetise each other, or to make new magnets, a very high degree of power can be obtained The natural magnet seldom possesses very great power for lifting It is much improved if it is trimmed into a regular shape, the poles being kept as far distant as possible and furnished with *armatures* (*q v*), which consist of soft iron pieces attached to the magnetic mass covering the poles, and brought round so as to project beyond it in the form of two feet In this way the lifting power of both poles is brought to bear upon the same mass to be lifted Even prepared in this way the natural magnet rarely lifts more than its own weight There are some remarkable instances on record in which this has been exceeded, but they are few The lifting power of the artificial magnet depends much upon its form, and the way in which it has been magnetised Dr Knight was particularly successful with his method of "*separated touch*" (*q.v*), whether it was from any peculiar advantage in the method, or from his own perseverance and skill But by far the most powerful permanent magnets are obtainable from magnetisation by means of the electric current This is performed by placing the bar to be magnetised in a spiral, through which an electric current is passing, and moving it backwards and forwards along the axis of the spiral In this way Logeman of Haerlem obtained magnets one of which would lift twenty-seven times its own weight, and which were exhibited at the meeting of the British Association in 1850 by Sir David Brewster. The lifting power of a magnet does not

increase in simple proportion to its mass Hacker gives a formula to express *P* the weight lifted by a magnet whose own weight is W.

$$P = a \times w^{\frac{2}{3}}$$

that is to say the weight lifted, *P*, is equal to a constant *a*, which depends upon the method of magnetisation, multiplied by the cube root of the square of the weight of the magnet Thus, if a magnet weighing 1 pound lifts 10 pounds, a similar magnet similarly magnetised and weighing 8 pounds would only lift 40 pounds It is found preferable, in order to obtain the greatest amount of lifting power, instead of using a large compact mass of steel, to magnetise a number of thin plates of the required shape and afterwards attach them together This is done by means of a soft iron armature which is fastened over the extremities of the bars, and which, in contact with them becomes, as has been already explained, itself a magnet Also in order to preserve the power of a magnet, another soft iron piece is made use of, which is called the *keeper* In the case of the horse shoe magnet, the keeper is a straight piece of very soft iron put in contact with both poles In the case of bar magnets, two or more are generally laid side by side with their opposite poles (see *Magnetism*) towards the same parts, and a soft iron keeper at each end connects them

Point of Saturation, Coercitive Force In magnetising a bar with a very powerful magnet, it is found that it is possible to communicate to it a greater amount of power than it can retain permanently There is, in fact, a limit for any particular bar to the intensity of permanent magnetisation, and if the bar be magnetised to a higher point it gradually loses its magnetism till it reaches this limit, after which, under ordinary circumstances, it remains constant The bar when magnetised as highly as possible is said to be *saturated* or to be *magnetised to saturation* The point of saturation depends entirely upon the molecular condition of the steel It has been already remarked that soft iron has not the slightest power of retaining magnetism, while hard steel possesses this faculty to a very high degree, and it is found also that magnetisation by induction takes place with greater readiness in soft iron than in steel There appears to be a force depending upon molecular arrangement which acts to prevent the assumption of the strained or polarised condition of the steel bar, but which, when once this strained condition has been taken on, in a similar way prevents the loss of it, or the change back to the natural state This force generally goes by the name of the *coercitive force*, though it cannot be said that anything very definite is known respecting it As a matter of fact, however, whatever changes the molecular condition of the bar alters the power which it has of acquiring and retaining magnetism A soft iron bar, if it be hammered or twisted while under the influence of a neighbouring magnet, may be permanently magnetised, but that which most of all affects this retentive powers is the temper of the metal Change of temperature also produces an effect upon a magnetised bar, the magnetic force being always diminished as the temperature rises If the changes are small, the bar does not permanently alter, and on cooling it again resumes its former force, but on being strongly heated it permanently loses a certain amount of its power, the loss depending on the temperature to which it has been raised, and when it attains a red heat it becomes completely demagnetised On the other hand, alteration of temperature may be made a means of magnetisation, thus if a bar be very strongly heated, as to redness, and then suddenly cooled while between the poles of a powerful magnet, it may permanently attain a very high degree of magnetic intensity

Distribution of Magnetism in Permanent Magnets It has been already stated with regard to natural magnets, that there are in general two points at which the magnetic force of the magnet appears to be concentrated This is even more evident in the case of artificial magnets If, for example, a bar magnet be thrust into a mass of iron filings, they are found to cover the extremities, hanging from them in thick bunches, while to the middle of the magnet, little or none adheres, and from the middle to the end, the quantity adhering is easily perceived gradually to increase Coulomb, by oscillating a small needle near to different parts of a large bar, examined the distribution of the magnetic force at different parts of it He found two places of greatest intensity, one at a short distance from each of the ends, thus in a bar 8 inches long he found them 1 6 inches from the extremities But what is really the case with regard to magnetised bars is this, that they may be considered as being made up of small elementary bars, each of which is itself a magnet, and that the force at any particular point is the resultant force of all the elementary forces acting Thus a bar magnet may be broken up into a number of very small pieces, and, when these are examined, each of them is found to be a magnet having its north and south poles lying in the same direction as those of the bar from which it is broken These, if again put in contact, as they were before breaking, will give the same effect as the original magnet

The properties of magnets are treated of under *Magnetism, Attraction and Repulsion, Magnetic, Induction, Magnetic*, and other names under which they are known The directive influ-

ence of the earth, which was adverted to at the beginning of this article, is considered under *Magnetism, Terrestrial*

MAGNETIC ATTRACTION AND REPULSION See *Attraction and Repulsion, Magnetic*, also *Magnet*, *Magnetism*

MAGNETIC AXIS See *Axis, Magnetic*

MAGNETIC BATTERY See *Battery, Magnetic.*

MAGNETIC CURVES See *Curves, Magnetic*

MAGNETIC DECLINATION See *Declination, Magnetic*, and *Magnetism, Terrestrial*

MAGNETIC DIP See *Dip, Magnetic*, and *Magnetism, Terrestrial*

MAGNETIC ELEMENTS The magnetic force at any place on the earth's surface is completely defined if its direction and magnitude are known, and these are commonly given by stating the magnetic *declination*, *inclination*, and *intensity*, which are called the *magnetic elements* The *declination* is the angle which a needle free to turn in a horizontal plane makes with the geographical meridian, the *inclination* is the angle which a needle, free to turn in the plane of the magnetic meridian, makes with the horizontal plane, and the *intensity* is the absolute amount of the magnetic force at the place, and is measured by ascertaining the velocity which would be imparted to a magnetic pole of unit strength, and unit mass, in unit time For the present year (1870) the magnetic elements are as follows at London —

	Declination	.	19°55′ W	
	Inclination	.	67°55′	
Intensity,	Horizontal Force .	.	3 83	Units being feet, grains, and seconds.
	Vertical Force .	.	9 49	
	Total Force .	.	10 24	

MAGNETIC EQUATOR See *Equator, Magnetic*, and *Aclinic Line*, and *Magnetism, Terrestrial*

MAGNETIC FIELD See *Field, Magnetic*

MAGNETIC FORCE, LINES OF See *Lines of Force, Magnetic*, and *Field, Magnetic*

MAGNETIC INCLINATION See *Dip, Magnetic*, and *Magnetism, Terrestrial*

MAGNETIC INTENSITY See *Intensity, Magnetic*, and *Field, Magnetic*

MAGNETIC MACHINE, or, *Magnetic Battery* See *Battery, Magnetic*

MAGNETIC MERIDIAN The plane of the *magnetic meridian* at any place is a vertical plane passing through the two points where the axis of a magnet, free to turn in a horizontal plane, cuts the horizon Duperry gave the name "magnetic meridians" to a system of curves which would be traced out by moving always in the direction in which a declination compass points These lines all terminate in the two magnetic poles, one in North America and the other south of Australia (see *Magnetism, Terrestrial*), and bear somewhat the same relation to each other and to the magnetic parallels as the geographical meridians do to each other and to the parallels of latitude

MAGNETIC MOMENT A term used in the mathematical theory of magnetism and in magnetic measurements In a uniform magnetic field two equal and opposite forces act upon the poles of the magnet tending to set it so that the line joining the poles may be parallel to the line of magnetic force The nature of this tendency is thus that of a *couple*, and if the magnet be placed perpendicular to the lines of force the amount of it is proportional to the intensity of the magnetic field, the strength of the poles, and the length of the magnet In a field of unit intensity, therefore, the couple will be measured by the product of the numbers expressing the strength of the poles and the length of the magnet, and this is termed the *magnetic moment*

MAGNETIC NEEDLE See *Needle, Magnetic*

MAGNETIC OBSERVATORY See *Observatory, Magnetic*

MAGNETIC OXIDE OF IRON See *Iron*, *Magnet*, *Loadstone*

MAGNETIC PARALLELS Lines drawn by Duperry at right angles to the *magnetic meridians* (*q v*) They bear the same relation to them that the parallels of latitude do to the geographical meridians

MAGNETIC POLES It is found that the places of greatest manifestation of magnetic force occur near to the extremities of a magnet, and these points are very generally called the poles of the magnet. The notions attached to the name *pole*, as used in common parlance, is, however, frequently very vague. Mathematicians define the poles of a magnet, with reference to the imaginary line called the *magnetic axis*, as the points where the magnetic axis is terminated by the surface of the magnet on each side

MAGNETIC SATURATION See *Saturation of a Magnet* and *Magnet*

MAGNETIC SOUNDS If an iron rod which is surrounded by a powerful coil is made to rest on a sounding board, and if currents are then sent through the coil, a tick is heard from

the rod each time the current is broken This noise has received the name of the *magnetic tick* If the current be suddenly caused to flow, and suddenly stopped by means of an ordinary contact breaker, or with the aid of a file (see *Break*), the tick is heard at each stoppage of the current The noise is attributed to a sudden shortening which the iron bar experiences on being demagnetised Wertheim showed that at magnetisation a bar is slightly lengthened, and at demagnetisation slightly shortened and Joule, experimenting on the subject, found in one case an elongation of $\frac{1}{180000}$ of the whole length of the bar The sounds produced in this manner have been made use of in the construction of an acoustical telegraph instrument (See *Telephone*)

MAGNETIC STORM Humboldt gave this name to violent disturbances in the earth's magnetism which take place from time to time The magnetic elements, that is, the declination, inclination, and intensity, are perpetually undergoing gradual and periodical change (see *Magnetism Terrestrial*), but besides these, there are sudden and great alterations in them which take place irregularly Thus a line traced out by a self-registering declinometer or inclinometer is always curved, and generally presents a regular wavy appearance, but besides this, sudden abrupt changes in its contour are displayed at times, indicating unusual disturbance It was soon observed that these disturbances have close connection with certain meteorological phenomena, and hence Humboldt's name, *magnetic storm* It is found that a magnetic storm is the universal concomitant of the aurora borealis "In the day that precedes the night in which an aurora borealis should appear," says De La Rive, "the declination of the needle to the west is always sensibly increased 10′, 20′, 30′, and even more

"At the middle and end of the appearance the needle deviates, on the contrary, more to the east than it should do in its normal state

"Finally, the needle frequently undergoes, during the period of the phenomenon of the aurora borealis, irregular oscillations, the amplitude of which may be some minutes of a degree"

The same is found to be the case with the aurora australis, and the other magnetic elements are likewise affected by them The influence of a magnetic storm extends itself over very large portions of the globe simultaneously it has been found that an aurora visible only in America or in Siberia is sensible to the magnetic needle at Paris

Little or nothing is known of the origin of the magnetic storm or of the aurora The aurora is pretty generally supposed to be due to electric discharges taking place through the attenuated air at a distance from the earth's surface, and the effect upon the needle to be that of a discharge taking place near to it, but whence these discharges and the electric excitement that produces them come is unexplained Sabine showed that for magnetic storms there is a decennial period of greatest frequency, which occurs simultaneously with a maximum period observed for auroras, and that this time coincides with that of the greatest frequency of solar spots It has been fully confirmed, that the occurrence of unusual sun spots is attended by unusual magnetic disturbance

MAGNETISATION, or the making of artificial magnets, is performed in two principal ways, first, by contact with other magnets, natural or artificial, and, secondly, by means of the electric current The making of artificial magnets requires great care, otherwise they are sure to be unevenly magnetised, or perhaps even to possess *consequent points* There are three methods by which the contact of other magnets is applied to magnetised bars these are commonly called the method of *single touch*, *separated touch*, and *double touch* Magnetisation by *single touch* is the simplest, and is performed in the following way The bar to be magnetised is laid on a table, and stroked from end to end with one extremity of a magnet, the stroking always taking place in the same direction, the magnet being lifted off after each stroke, and brought back to the first end again After twenty or thirty applications the bar is turned over, and the same operation performed on the other side, and *in the same direction* When this is done, the bar will be found to be magnetised, that end of it at which the magnetiser always left it possesses the opposite magnetism to that of the pole with which it was stroked It is very difficult by this method to give even magnetisation, nor are the magnets produced so powerful as those made by the methods about to be described Its recommendation is its simplicity

Magnetisation by separated touch was invented by Dr Knight in 1745, and afterwards improved by Duhamel As now performed four magnets are used Two of them are placed on a table, with their poles a short distance apart, the opposite poles being near to each other, and the bar to be magnetised is placed with its ends resting on them Two other magnets are then taken and placed with their extremities, one a north end, the other a south end, resting in the middle of the bar, a little billet of wood being placed in the middle to prevent them from touching The magnets are then drawn out to the ends of the bar as evenly as possible, the one whose north end rests on the bar going towards the extremity of the bar that rests on the

north end of a supporting magnet The magnets, when they come to the ends, are lifted up and brought back without touching to the middle, and again drawn outwards in the same way. The bar is afterwards turned over and stroked similarly on the other side This method gives very powerful and at the same time very even magnets

The method of *double touch* was invented by Mitchell. Four magnets are also used in it, the arrangement being similar to those for separated touch, but in stroking the bar, instead of drawing one magnet to each end, the two are moved backward and forward together from end to end, and finally lifted off in the middle Very powerful magnets are made by this method, but they are wanting in evenness But by far the most powerful magnets are obtained from magnetisation by means of the electric current The bar to be magnetised is placed in the axis of a spiral of copper wire, the spiral being at the middle of the bar A powerful electric current is then made to pass through the wire, and the bar is moved backwards and forwards in the direction of its length After a few passings, it is again brought to its old position with the spiral in the middle of it, and the current is stopped Extremely powerful magnets were made in this way by M Elias of Haerlem, and Logeman, who, however, kept the details of their process secret

MAGNETISATION OF LIGHT See *Circular Polarisation, induced by Magnetic Action*

MAGNETISATION PRODUCED BY THE SUN'S RAYS It is somewhat doubtful whether sunlight shining on a steel needle will confer magnetic power on it Some experimentalists have recorded that by concentrating the violet end of the spectrum upon one end of a needle, it conferred magnetic properties upon it, but others have repeated the experiment unsuccessfully It is possible that some such action would be produced under favourable circumstances, but the experiments require verification

MAGNETISM The science of magnetism treats of the properties of certain bodies called *magnets*, which are primarily known from the power they possess [illegible] its compounds It will be our business here to unfold these properties [illegible] of the magnetic to other known forces, but since, owing to the arrangement of this work, the particular portions of each subject are necessarily discussed under their respective particular names, we shall be obliged to assume, to avoid circumlocution, that the reader is already to a certain extent acquainted with some of them, merely giving references here which will enable him to make himself so, if he be not Under the words *Magnet, Magnetisation*, will be found an account of these bodies themselves, and of the method of making them, we shall generally throughout this article understand by a *magnet* a bar of steel endued with the property of attracting iron and with certain others which we are about to specify

Distribution of Magnetic Force If a small ball of soft iron be suspended by a thread, and if a magnetised bar be brought near it, it will be found that each end of the magnet will attract the ball, but that the middle of the bar possesses no attractive power at all Or if a small cylinder of iron suspended from the arm of a balance be used, and a magnet passed from end to end under it, it may easily be shown that at the extremities of the bar there is a very powerful attractive force which gradually diminishes to zero as we approach the middle The same thing may be very beautifully shown, if the bar be rolled in iron filings, the filings adhering to the different parts of it in proportion to the attraction which those parts possess It has been shown by Coulomb, by means of his torsion balance, that two points of maximum attraction exist, one near to each end of the magnet, and these are frequently called the poles of the magnet Coulomb showed that for a short bar the distance of the point of greatest intensity from the end is one sixth of the length, and that the thinner and longer the bar is the nearer is this point to the extremity of it With regard to the internal distribution of the force but little that is satisfactory is known Coulomb tried to examine it by tying bundles of bars together and determining their combined as well as their separate force Nobili also investigated the subject, and he found that the force obtained by putting magnets together in this way does not at all increase in proportion to the number of bars It appears also from other considerations that in a magnetised bar the intensity of the magnetisation decreases as we go towards the interior, and that it may be looked upon as made up of layers of magnetized matter, the inside layers being less magnetised than those exterior to them When a magnetised bar is broken up it is found that each little portion is itself a magnet, its poles being in the same direction with regard to each other as were the poles of the entire magnet, and if the pieces are again put in contact, the original magnet is reformed with no alteration, except, perhaps, a little weakening of magnetic power due to disturbance in breaking it

Action of Magnets upon Magnets It is well known to all, that a magnet, when suspended so as to be capable of turning round a vertical axis perpendicular to its length, places itself so as to point nearly north and south, the same end invariably pointing in the same direction Of this the mariner's compass is a sufficiently familiar example. From this property one end is distin-

guished from the other, and by English writers that end which points northwards is called the *north end*, that which points southward the *south end*. Continental writers designate them differently and with more reason (See *Magnetism, Terrestrial*) If two magnets be brought near to each other, north end to south end, attraction takes place between them, if, on the other hand, a north end be presented to a north end, or a south end to a south end, repulsion is manifested Hence we have a distinction between the forces exerted by the two ends of a magnet, and the rule that *like poles repel each other and unlike attract* The laws which govern the action of one magnet upon another were examined by Coulomb in the case of very long and very thin bars by means of his torsion balance, and he came to the conclusion that *both for attraction and repulsion, the force exerted between two poles varies inversely with the square of the distance between them*, and *that forces equal in amount, though opposite in direction, are exerted by the poles of the same magnet upon one pole of another magnet* These laws, when mathematically expressed, have been always received as the foundation of the dynamics of magnetism See a paper by Sir W Thomson in the Philosophical Transactions, Part I for 1851, on "*A Mathematical Theory of Magnetism*"

Action of Magnets upon Bodies not in themselves Magnets It is mentioned above, and has long been known that magnets attract soft iron This is due to the property which magnets have of conferring upon certain bodies, not in themselves magnets, *temporary* magnetism, and the action which goes on is called *magnetic induction* If the ends of a bar of soft iron in the neighbourhood of a permanent magnet be examined, they will be found to possess all the properties of a magnet Thus, if the north end of a magnet be brought near to one end of the soft iron bar, it will be found that both ends of the latter have an attractive power for other masses of soft iron, and that the end near to the permanent magnet is a south pole end, the remote end a north pole The induced southern magnetism in it and the northern magnetism of permanent bars attract each other Repulsion of course takes place between the induced northern magnetism of the soft iron bar and the northern magnetism of the permanent magnet, but owing to the difference of distance in the two cases, the attraction on the whole prevails This inductive effect may be propagated still farther Thus, suppose a small cylinder of soft iron to be allowed to attach itself by attraction to a magnet, magnetism of the kind similar to that of the pole with which it is in contact is developed at the remote end of it By means of this a second cylinder may be attracted, induction taking place in it also, and in the same way a third and fourth As soon, however, as the cylinders are removed from the influence of the magnet the attraction which they have for each other at once ceases, the whole chain falls to pieces, each cylinder having returned to its natural state So much has long been known with regard to the action of magnets upon bodies not permanently magnetised, and it was also known that a few other bodies, such as nickel and cobalt are similarly affected, but it was reserved for Faraday to show that every body without exception is subject to the magnetic influence, and for him and Thomson to revolutionise the whole magnetic theory

According to Faraday's explanation, the action of a magnet is to be conceived of as spreading all round it in "*lines of force*," and he speaks of the space through which the magnetic influence extends as a "*field of force*" or a *magnetic field* Close to the magnet, the lines of force are very concentrated, and the intensity of the magnetic field is very great, the lines of force then radiate out in all directions, they are not, however, straight lines, and the intensity decreases the farther we proceed from the magnet He showed that all bodies may be placed in a series according to the tendency which they have to occupy the intense portion of the magnetic field The following is his arrangement of them —

Iron	Crown Glass	Copper.	Cadmium
Nickel	Platinum	Silver	Tin
Cobalt	Osmium	Lead	Zinc
Manganese.	Air and Vacuum.	Water	Heavy Glass
Chromium.	Arsenic.	Mercury	Antimony
Cerium	Ether	Sodium	Phosphorus.
Titanium.	Alcohol.	Flint Glass.	Bismuth
Palladium	Gold		

Suppose now that a mass of soft iron is suspended in air in the vicinity of a magnet Since the iron has a greater tendency than the air to occupy the part of the magnetic field of highest intensity—that is, the part nearest to the magnet—it moves into it, in fact, it is attracted On the other hand, a crystal of bismuth possesses less tendency than does the air to occupy a place of high intensity, and it therefore gives place to the air—that is to say, it is repelled The same is true of these bodies when they are placed *in vacuo*, air and vacuum having the same magnetic power, nor is the result altered by increasing or diminishing the density of the air.

Hence Faraday was led to assign to air and vacuum the zero of magnetic power, and to call those bodies which rank above vacuum, such as iron, *paramagnetic bodies*, those which, like bismuth, rank below it *diamagnetic bodies* The word *magnetic*, he says, ought to be general, and to include all the phenomena and effects produced by the power We regret that our space does not permit us to enter more in detail into these wonderful discoveries An account of the experiments which led to them is to be found under *Diamagnetism*, and under *Lines of Force*, and *Field, Magnetic*, are given the outlines of that which now forms the basis of the mathematical theory Faraday's own beautiful experiments are published in the Phil Trans, 1846, 1849, 1850, and those specially on Lines of Magnetic Force, in 1852, and in the Royal Institution Proceedings, Jan 23, 1852

Effect of Magnetism on Light and Heat Information on this subject will be found under *Circular Polarisation induced by Magnetic Action* We merely mention the effect here When a ray of light or heat passes through a Nicol's prism, it is *polarised*, and a second Nicol's prism, placed so that its principal section is perpendicular to that of the first, completely cuts off the ray But when certain substances are put between the two prisms, the light or heat appears again, the plane of polarisation having been altered This is the case with light, as was shown by Faraday (*Phil Trans*, 1846), if a plate of glass, under the influence of the poles of a very powerful magnet, is arranged in this position, and it was from experiments on this subject that he was led to his discovery of diamagnetism Wartmann subsequently extended the observation to heat when a plate of rock-salt is similarly used The laws of this phenomenon were carefully examined by Faraday, and afterwards by other observers, and the amount of rotation by various transparent bodies recorded

The Directive Action of the Earth upon Magnets is treated of fully under *Magnetism, Terrestrial*, and the action of currents upon magnets, and of magnets upon currents, under *Electro Magnetism* and *Magneto-Electric Induction*

Theories of Magnetism The first theory of magnetism, leaving out the old poetic theories of the Greeks, which endowed the magnet with a spirit, or supposed it to emit an effluvium which, spreading from the magnet, seized and dragged the iron towards it, assumed the existence of two magnetic fluids, a northern fluid and a southern fluid These were supposed to attract each other, and to be each of them repulsive of itself In the natural condition, a mass of iron contains these fluids intimately united, and in equal quantities, and the whole mass is then in a neutral condition, but when a mass of soft iron is brought near to one pole of a magnet, the fluid at that pole attracts the opposite fluid which pervades the iron bar towards itself, and repels the other, namely that which is similar to itself, to the remote end of the bar, and so the soft iron becomes for the time a magnet On removing the magnet, the two fluids meet together again and recombine In the case of steel, however, things are somewhat different, for in it exists the *coercitive force* which, in the first place, acts against the separation of the two fluids by induction But when the separation is accomplished, as by one of the processes of magnetisation, the coercitive force acts so as to prevent their recombination, and thus we have a permanent magnet According to this view, however, if a bar of soft iron were divided in the middle while under the influence of a magnet, or if a permanent magnet were broken, one half would have an absolute charge of northern magnetism, and the other of southern magnetism, but this we know is not the case, for the pieces of a broken magnet present a pole at each end, and, in fact, such a thing as an absolute charge of one or other fluid is altogether unknown to us To meet this difficulty, it is supposed that the molecules, of which the magnet is composed, contain or are surrounded with these fluids, and that the action of induction or of magnetisation is to separate it with regard to them Each little molecule would thus be a magnet, and the aggregate effect of them would be to give poles at the extremities of the bar, such as those which we know magnets to possess

A more recent theory supposes that all magnetic substances, such as iron, nickel, cobalt, are composed of particles each of which is a permanent magnet, but in the ordinary unmagnetised state, the little magnets have their poles turned in all directions, so that one neutralises the effect of the other The process of magnetisation, whether by induction or in any other way, is considered to have its effect in turning all the north poles one way, and the south poles the opposite, and thus producing the northern and southern forces as general resultants of the whole.

The celebrated theory of Ampère is very different from any of these Observing the intimate relations of electric currents to magnets, and the attraction and repulsion exerted between magnets, and wires transmitting currents, and also between two wires, each of which causes a current, he formed the theory which we shall now explain We must refer, however, to our article on *Electro-Dynamics* and *Electro-Magnetism* for the proofs of some of the facts Suppose that we have two helices of copper wire, or *solenoids*, as they are called, and that the current,

after entering, passes through the helix always in the direction of the hands of a watch, and let these be made moveable about an axis, perpendicular to the axis of the helix. Then, on bringing near to each other the ends at which the current enters, or the ends at which the current leaves the solenoids, repulsion will be found to take place, and on bringing near one of the ends at which the current enters, a solenoid, and the end at which it leaves the other attraction is exhibited just as would be the case if the like and unlike ends of two magnets were presented to each other. Moreover, if the north end of a permanent magnet be brought near to the end at which the current enters one of these solenoids, that end is attracted, and if it be brought near to the end at which the current leaves the solenoid, repulsion takes place. Lastly, a solenoid free to move obeys also the laws of terrestrial directive force, just as does a magnet. Ampère, therefore, supposes a magnet to be practically a solenoid, in which the current enters at the south pole, and travels in a spiral round it to the north, the motion taking place, so that an observer, looking at the south pole, would see the current move in the direction of the hands of a watch. He supposes that magnetic bodies in their natural state are made up of molecules, round which currents are always circulating, and that, when unmagnetised, these currents are circulating in all directions, and thus the effect of the whole is neutral. But when the body is magnetised, the currents are all turned round so as to flow in one direction, the direction being that of the hands of a watch to an observer looking on the south pole, while the north pole points away from him. The general effect of the whole is to present a body at whose exterior currents are circulating, and which acts precisely as a solenoid would.

MAGNETISM, CORRELATION OF. Numerous illustrations of the connection of magnetism with the other physical forces are to be found in consideration of the phenomena discussed throughout this volume. It is to be observed, with respect to the dynamical relations of magnetism, that they differ essentially from those of mechanical force, heat, light, electricity, motion, chemical action, each of which, when properly directed, *gives rise to* the other forces. Magnetism is static, and that it may occasion kinetic phenomena motion must be superadded to it; its action is directive, not motive; it determines the conversion of one kind of force into another, but it does not initiate any. Thus a magnet might remain for ever unknown if its position were not altered with regard to other bodies; but, on moving it towards or from masses of soft iron, its attractive power is at once recognised; on moving a closed wire about in its vicinity, electric currents are set up which may give rise to heat, light, and chemical action, while, at the same time (see *Lenz's Law*), resistance to the motion of the wire is experienced; change in temperature, and change in the magnetic state of a bar of iron, too, follow each other.

Let a bar of soft iron be placed between the poles of an electro magnet, and let currents be suddenly sent into the electro magnet, and suddenly stopped, so that the soft iron bar between its poles will successively be magnetised and demagnetised, it will be found easy, while great care is taken to screen the bar from heat conducted or radiated from the electro magnet, or while the latter is kept cool by immersion in water, to raise the temperature of the soft iron bar through several degrees; or, let the following experiment be made, let a mass of soft iron be allowed to move very slowly up to a permanent magnet, and then let it be drawn away to its initial position so rapidly, that when it arrives there it has not lost the magnetism it possessed by induction, while it was close to the magnet. In this operation work is expended, for in moving towards the magnet slowly it had at each instant only the amount of magnetisation due to its position at that instant, while, during the backward motion, it possessed the whole magnetisation due to its position when nearest to the magnet; the backward movement was therefore performed against forces more powerful than those which favoured the approach. But soon the magnetisation has entirely disappeard, and the soft iron mass is left in the same condition as it was before the series of operations. What, then, has become of the work that has been done upon the mass? According to the experiments of Joule an amount of heat is generated in the iron, precisely equal to that which might have been obtained by applying the work in the way of friction to raise the temperature of it.

MAGNETISM, TERRESTRIAL. It has long been known to us, and is said to have been known for ages to the Chinese, that the earth possesses a power of directing a suspended magnetised bar, similar to the directive power which one bar has upon another. Hence the earth is looked upon as a great magnetic mass, and the phenomenon just mentioned, and which we are about to treat of in some detail in this article, is said to be due to *Terrestrial Magnetism*.

Let a steel bar be suspended at its centre of gravity so as to be capable of turning at the same time round a vertical, and round a horizontal axis, which is easily done by making it turn upon a horizontal axis through that point, and supporting the bearings of this axis by means of a fine silk thread. In this case the bar will be indifferent to position, and will, in fact, if pro-

perly suspended, remain in any position in which it may be placed, without tendency to move, except a torsional force, which may be made very small, be exerted by the silk thread Now let it be magnetised, and it will be found to be no longer thus indifferent, it will take up a definite direction, and will return to the same position if displaced from it The direction of the bar depends upon its locality on the earth's surface Roughly speaking, it points north and south, and hence one end of it—namely, that which points to the north—is called by English* writers the north pole of the magnet, the other the south pole In most localities the direction of the magnetic axis of the bar makes a certain angle with the plane of the geographical meridian, and also dips downwards, that is, makes an angle with the horizontal plane In England, for example, the needle turns its north end to the west of the geographical north and south line, and makes with it an angle of about 20°, while the angle made with the horizontal plane is about 68° The former of these angles is called the *declination*, the latter the *inclination*, of the needle, and these two angles, and the intensity of the force exerted on the needle or the *magnetic intensity* as it is termed, are called the *magnetic elements* The determination of the magnetic elements at different places and different times, and of the variations to which, as we shall see, they are subject, is the object of magnetic observers and observatories We proceed to explain how this is done, and to give the laws of the phenomena of terrestrial magnetism, and the theories which have been put forward to account for and collocate them We wish, however, to make one or two preliminary remarks *First*, On the nature of the influence exerted by the earth on a magnetised needle If we bring a needle freely suspended near to an ordinary bar magnet, there is, in the first place, a directive tendency owing to which the magnetic axis of the needle takes a definite direction, but there is also a force causing the needle to move bodily towards the bar, which results from the fact that the dissimilar pole of the needle is perceptibly nearer to the pole of the bar magnet than the like pole But in the case of the earth it is not so, and any influence which is exerted on the needle is directive It is, in fact, of the nature of a couple (see *Couple*) tending to turn the needle round the axis of suspension For, if we consider the earth as a vast bar magnet (which we may roughly do for the present), it is evident that, owing to the vast distance of the poles, there will be just as much repulsion from either pole of it on the like pole of the needle, as there is attraction on the dissimilar pole This may easily be exhibited experimentally by floating a light needle on a cork in water when the directive tendency will be evident at once, but without bodily motion in any direction The second remark we wish to make is this, that it is convenient, in speaking of the magnetic force, whose direction, as we have already mentioned, is in most cases inclined to the horizontal plane, to speak separately of the *horizontal* and *vertical* components These are to be understood to be obtainable from the total force by the ordinary rules for the composition and resolution of forces (See *Composition of Forces*, *Resolution of Forces*)

Determination of Magnetic Elements The magnetic declination and inclination are for convenience determined separately, the former by instruments called *declinometers*, the latter by the *inclinometer* or *dipping needle* A declinometer consists of a magnetised needle, capable of turning with great ease upon a vertical point It turns over a horizontal card graduated to degrees and quarters of a degree Parallel to the line passing through 0° and 180° is a telescope, turning round a horizontal axis, and furnished with the appliances necessary for determining the altitude of the sun or stars, and the instrument is set upon a stand, provided with a spirit level and levelling screws All the fittings are, of course, of brass or copper, iron being carefully excluded To determine the angle of declination, the geographical north and south line is ascertained by taking the altitude of some heavenly body, and the zero line of the compass card is made to coincide with it The angle of declination, or the angle which the direction of the needle makes with this line, can then be read off on the graduated circle over which the needle turns There are other forms of instrument for the same purpose

The magnetic *inclination* or *dip* is determined by observing the inclination to the horizontal plane of a needle turning on the vertical plane which passes through the magnetic north and south points A magnetised needle is supported upon a horizontal axis through its centre of gravity Round it, in the plane in which it moves, is a circle of brass finely divided, so that the point of the needle moves along just within the divisions. The circle, and needle within it, are carried on a vertical pillar, the foot of which turns in a graduated horizontal circle To observe with this instrument, it is first necessary to place the vertical circle and needle in the plane of the magnetic meridian The pillar which carries it is turned round till the needle points vertically down, and it is evident that when it does so, the plane of the vertical circle is at right

* This is not the case with continental writers, and with very good reason, for the earth is considered in the light of a magnetised bar of steel, and, in the latter case, it is *not* the *north* end of a magnetised needle, but the *south* end which points to the *north* of the other

angles to the plane of the magnetic meridian, for then the only force which acts upon the needle is the vertical component of the earth's magnetism A reading is then taken upon the graduated circle at the foot of the pillar, and the pillar is turned through 90 by means of it, and that being done, we know that the plane of the vertical circle must coincide with that of the magnetic meridian, and the angle of inclination can be read off by the graduation around the needle Other instruments are described under their proper heads (See *Balance*, *Bifilar*, *Magnetometer*, *Declinometer*, and *Observatory, Magnetic*)

The intensity of magnetic force is also determined by means of the declinometer The whole directive force that acts upon it is, as we have seen, the horizontal component of the earth's magnetism, but if we can determine it, it is easy, since we know the direction of magnetic dip, to calculate, by the well known rules for the composition and resolution of forces, both the vertical component and the total magnetic force To ascertain the horizontal component of the earth's magnetic force, the declinometer needle is made to oscillate, and the number of oscillations made in a given time is counted From this observation it is evident that the force acting upon the needle can be determined just as the force of gravity is calculated from observation of the number of oscillations performed in a given time by a pendulum of known length The force exerted by the earth upon a bar depends, however, both on the intensity of the earth's magnetic force, and on the strength of the magnetic needle, and to know the former it is therefore necessary to determine the latter This is done by bringing into the vicinity of the needle another similar needle, and noting the effect which they produce upon each other, as compared with the effect which the earth's magnetism produces upon each This method is due to Gauss, as is also the method of expressing magnetic force in *absolute units*, that is, in units depending only on the defined units of length, mass, and time Unit of force, being that force which, acting on unit of mass during unit of time, produces unit of velocity, a unit magnetic pole is defined to be a magnetic pole, which, if placed at unit of distance from a similar magnetic pole, exerts unit of force upon it In English magnetic measurement, the unit of length is one foot, the unit of mass one grain, and the unit of time one second Hence the above statement takes the following form —Unit of force is that force which acting for one second on a mass of one grain, would give it a velocity of one foot per second, and a unit magnetic pole placed at a distance of one foot from a similar pole, exerts upon it unit of force When then we say that the total magnetic intensity expressed in British units is 10 24 (as it is at present, 1870, at London), we mean that a unit north pole, weighing one grain, if acted upon for one second by the earth's magnetic force, would acquire a velocity, in the direction indicated by the dipping needle, of 10 24 feet per second

Having given this short account of the methods of determining the magnetic elements, we proceed to recount what has already been ascertained with regard to them and their variations In the field of magnetic observation has been displayed the most arduous and devoted scientific working, and a full account of it may be found in the treatise of M De La Rive To Halley belongs the honour of commencing, in a systematic way, the putting together of the ascertained facts In 1701 he returned from a voyage, undertaken with the special object of making magnetic observations, and published a chart, in which his results were displayed in the form of lines connecting places of equal declination From that time there were many observers, but it is since the beginning of the present century that the greater part of the knowledge we possess has been collected Hansteen published in 1819 a work on terrestrial magnetism, which contained charts of lines of declination for 1600, 1700, 1710, 1720, 1730, 1744, 1756, 1787, and 1800, and of lines of inclination for 1600, 1700, and 1780, and among many other names stand prominently those of Rossel, who commenced observations on magnetic intensity, Duperrey, Barlow, Ross, and Sabine But to Humboldt, perhaps more than to any other, we are indebted, both directly and indirectly, for our knowledge on this subject In 1819, feeling that no amount of private inquiry would be sufficient to give us adequate results, he applied to the Russian Government for aid, and obtained a liberal response in the establishment of stations for magnetic observations in various parts of the Russian Empire, and some time after, with the support of the Royal Society, and of the British Association for the Advancement of Science, he brought the matter before the British Government, and with like success Chief observatories were instituted at Dublin and Greenwich, and a large number of other establishments were set up at different distant stations, in the most advantageous positions One was placed at Toronto, in Canada, and another at Hobart Town, in Van Diemen's Land, these being points nearly the antipodes of each other, and also being situated near to the places of greatest magnetic intensity, a third was established at the Cape of Good Hope, and a fourth at St Helena, which was chosen from its vicinity to the line of minimum intensity, and to the magnetic and geographical equators But the most celebrated of all the observatories is that which had been established

at Gottingen, under the direction of the illustrious Gauss and Weber From Gauss proceeded the whole system of observation, and to him is due the invention of all the most delicate instruments, and of the most perfect methods of observing and co-ordinating the phenomena The direction of the foreign observatories belonging to Great Britain was put under Colonel Sabine, and he was furnished with a considerable staff of military assistants, so that the work might go on night and day without intermission All the observations were made simultaneously, and were regulated by Gottingen mean time Under ordinary circumstances they were made every hour, but in cases of magnetic disturbances much more frequently By these means, and with the assistance of voyages and expeditions undertaken for the purpose, a very large amount of information was collected, the definite objects being to determine the magnetic declination, inclination, and intensity at various places, to determine the lines of equal declination, inclination, and intensity, and to ascertain the laws which regulate the periodical and also extraordinary variations of the magnetic elements The mass of information collected by the British observatories was worked into a manageable form under Sabine, and was published under his direction, with dissertations by him, together with graphical representations and charts of the magnetic curves

The following are some of the results arrived at —First, with respect to the *isogonic* lines, or lines of equal declination, they are, as has been explained, such as would be traced out on a globe by joining all the points on it at which the angle of declination is the same Sabine's charts will be found in Johnston's Physical Atlas On examining them it will be seen that they have a general direction from north to south, with a few remarkable exceptions, and appear to terminate in two points, one in the northern hemisphere, somewhat to the west of Baffin's Bay, the other in the southern, to the south of Australia In Sabine's map for 1840 the line which passed through the south of England is marked 25° W It passes thence across the Atlantic ocean, bending downward to the south a little, enters North America south of Newfoundland, and thence strikes northward through Hudson's Bay At any place along this line a declination needle or a mariners' compass would indicate a point 25° to the west of the true north A very important line is the line of no declination, or *agonic* line, that is, a line such that, at every point along it, a declination needle would point to the true geographical north There are two such lines, one in the western and the other in the eastern hemisphere The first, passing northward through the South Atlantic, cuts off the eastern corner of South America It enters North America and passes, not far from New York, through the American lakes and through the west of Hudson's Bay The other passes, southward from the White Sea, through the east of Russia, and, cutting the Caspian Sea and the eastern coast of Arabia, curves through the Indian Ocean to the west coast of Australia, where it turns south again Throughout the space between these two lines, taking in Europe and part of America, the declination needle everywhere points to the west of north, throughout the space between them on the opposite side of the globe, taking in China, India, and the remainder of America, the declination is easterly

The general appearance of the *isoclinic* lines, or lines of equal dip, is that of curves approximately parallel to the parallels of latitude The dip increases as we proceed northward, and southward, from a certain line called the *aclinic* line, or line of no dip, and frequently the magnetic equator, which lies not far from the geographical equator, cutting it in two points, one in Africa and the other to the west of South America, and lying to the south of it in the Atlantic, and to the north of it on the other side of the globe The line marked 70° passed in 1840 through England, and, bending a little southward, cut North America, the eastern portion to the south, the western to the north of latitude 40° There are two points at which a dipping needle would point vertically, one in the northern hemisphere and the other in the southern, these are called the magnetic poles, and round them the isoclinic lines form a set of concentric curves, bearing much the same relation to them that the parallels of latitude do to the geographical poles The former of these points was found by Captain Ross in 1831 in lat 70° 50′ N and lon 263° 14′ E The position of the southern magnetic pole has been calculated from observations made at Hobart Town, Van Diemen's Land, and lies in lat 66° S and lon 146 E

The *isodynamic* lines, or lines of equal magnetic intensity, have also been laid down by Sabine As we approach the lines from a certain line of minimum intensity the total intensity increases. This line lies near to the magnetic equator, though it does not coincide with it, and the isodynamic lines are *nearly* parallel to the lines of equal dip It appears, however, that the points of greatest intensity do not coincide with the magnetic poles There are, in fact, more than two points of maximum intensity In the northern hemisphere two have been found, one in North America, about 16° to the south of the north magnetic pole, and the other in Siberia, at lat. 71° 20′ N, lon 119° 57′ E Gauss has shown by calculation that in the southern hemisphere there is but one point of maximum intensity, which is situated 2° 26′ to

the north and 7° 56′ to the east of the southern magnetic pole. Of these, the last is the strongest, and that near Hudson's Bay stronger than the other; the numbers which express their intensities are respectively 2·26, 1·76, and 1·69, the total intensity at London being expressed by the number 1·37.

We have now to consider the variations to which the magnetic elements are subject. There are two kinds, *regular* and *irregular*.

It soon became evident, on comparing together the numbers which express the angles of declination and dip, that from year to year slow changes are taking place. Thus in 1576, the first year for which we have a recorded observation, the declination needle at London pointed 11° 15′ East, in 1652 the declination was 0°, and in 1760 it had attained a westerly declination 19° 30′. The westerly declination increased till 1815, when it was 24° 27′, its maximum value; it then began to decrease, and still continues to do so. In 1815 it was 22° 29′, in 1865 21° 6′, and in 1870, 19° 15′. The annual decrease of declination at London is about 8′. In London the dip is likewise decreasing at present at a rate of about 2·6′ per annum, and it has been steadily decreasing ever since the first recorded observation. In 1720 it was 74° 42′, in 1800, 70° 35′, in 1865, 68° 9′, in 1870, 67° 55′. According to Hansteen, however, it will attain a minimum, and, after that, it will commence to increase again. There is a similar change taking place at all places on the surface of the earth, the amount and direction of the change depending on the position of the place. At Paris the variations have been very similar to those observed in London. At the Cape of Good Hope the declination in 1605 was 0° 30′, the maximum declination occurred in 1791, when it was 25° 40′, and after that it began to decrease. Again, in Russia (and this confirms M. Hansteen's ideas) the inclination has already attained a minimum, while in Pekin it is on the increase.

Such variations as these are called *secular*, taking, as they do, ages for their completion; and, besides these, there are both *annual* and *diurnal* variations. If the declination, and dip, and intensity are observed from hour to hour, it is found that changes are taking place which have for their period of completion a single twenty-four hours; and on computing the mean values of these observations from day to day, variations having an annual period are discovered. At Kew Observatory the following is the nature of the diurnal change in declination, and it may be stated that similar changes take place in other localities, following the hours of local time. —At about 22 hours (10 A.M.), and a little before 7 hours (7 P.M.), the needle is in its mean position. Between these hours during the day the declination increases; that is, the north end of the needle turns westward. At 1 hour (1 P.M.) it attains its maximum point, which is about 6′ to the west of the mean; from 1 to 7 o'clock it is gradually falling back. It then proceeds eastward from the mean position, attaining a maximum at 20 hours (8 A.M.), and being then 4′ to the east of the mean. During the next 2 hours it falls back to the mean position again. The inclination has also a variation of diurnal period. Arago places the maximum at 8 in the morning, and the minimum at about 3 in the afternoon. The amount of variation is not more than 3 or 4 minutes.

The annual variation of the declination takes place as follows: from April to July the needle slowly moves eastward, and during the remaining nine months of the year in the opposite direction. Thus, during the interval between the spring equinox and the summer solstice the declination is decreasing, and it slowly increases again during the autumn and winter months of the year. The amplitude of the variation, which, however, varies from time to time, and is different in different places, is at present about 59″ at Kew. There is also an annual variation of the magnetic dip. At present, at Kew, the amount of it is 0·54′. During the six months from April to September the dip is on an average 0·27′ lower, and during the other six months 0·27′ higher than its mean. See a paper on the results of six years' observations at Kew, ending 1868·9, by Dr Balfour Stewart, Proceedings of the Royal Society, March 1870. The annual variation of the magnetic intensity is, if it occur at all, very slight.

Our limits permit us only this very brief sketch of a most interesting and important subject. The reader may consult for full information on the whole subject of terrestrial magnetism an excellent chapter in De La Rive's treatise on electricity, vol. III. Also the papers of Sabine, with tables and charts, which are to be found in the Phil. Trans. from 1840 and more recently.

Lastly, there are, as we have already mentioned, irregular variations of the magnetic elements. Besides the slow and periodical changes we have just been speaking of, it is found that sudden temporary alterations, frequently of a very considerable amount, take place. Humboldt has given to these disturbances the name of magnetic storms, and they have attracted from all observers the greatest possible interest. It has been proved that they are intimately connected with the occurrence of the aurora borealis. Immediately before the appearance of this phenomenon the needles are powerfully disturbed, and the same is the case after it; and during the display, sudden alterations, amounting in the case of the declination sometimes to

one or two degrees, are observed Sabine has shown that there are periods of greatest frequency of the magnetic storms occurring every ten years, and that these times are the same as those at which the sun's spots are most numerous.

To account for terrestrial magnetism various hypotheses have been put forward, which it will be sufficient merely to mention here Their chief value is of course to assist us in the co-ordination of facts, and to indicate the directions in which we are to look for general laws The first theory was that of Gilbert, who supposed the earth to contain a great magnet with its poles situated near to the geographical poles of the earth If a short needle be magnetised and suspended horizontally by a fine thread, it may be made to take position very similar to those of the declination and dipping needles, by carrying it about in the vicinity of a very long bar magnet Halley, however, showed that the complication of the magnetic curves is such as not to admit of this simple explanation He supposed two magnets of unequal strength to cross each other at the earth's centre, and calculated the curves under that hypothesis The theory of Halley was supported by Hansteen Barlow, in order to account for the existence of magnetism in the earth, supposed it to be perpetually traversed by electric currents taking place from east to west Taking a globe, he rolled round it a copper wire in a spiral, and caused a current to circulate in it, and he was able, on bringing near to it short needles suspended, to show the phenomena of declination and dip But Gauss, putting aside altogether hypothetical causes, undertook the following problem supposing the whole earth to be magnetic, he calculated what must be the distribution of the magnetism in order to give the influences known by observation to exist

MAGNETISM, THEORIES OF See concluding part of the article on *Magnetism*

MAGNETO-ELECTRICITY For information on the connection between electricity and magnetism, see *Electro-Magnet*, *Electro Magnetic Machine*, *Electro-dynamics*, *Induction*, *Electro-Magnetic*, &c

MAGNETO-ELECTRIC MACHINE It is explained (see *Electro dynamics* and *Induction*, *Electro-Magnetic*) that, on bringing a permanent magnet near to a coil of wire, or on removing it from the coil, electric currents are caused to flow in the coil, the first inverse, the second direct, as compared with Ampère's hypothetical currents (See *Ampère's Theory*) Suppose, for example, that we suddenly thrust a permanent bar magnet into the core of a hollow coil of wire, a momentary current is produced in one direction, if, then, we suddenly draw it out again, a momentary current is produced in the opposite direction Or, still better, suppose that we have a coil of wire round a core of soft iron, and that we bring near to the extremities of the soft iron core a permanent horse shoe magnet, the soft iron is at once converted by induction into a magnet, and a current through the wire is set up On drawing away the permanent magnet, an opposite current is caused to pass This Faraday showed in 1831, and on this depends the action of electro magnetic machines

In the simplest form of magneto-electric machines, a pair of bobbins of wire coiled upon soft iron cores is revolved in front of the poles of a powerful horse-shoe magnet The wire of the two bobbins is continuous, and it is wound upon the soft iron cores in such a way that, looking upon the faces of the cores, the direction of the winding on the two is that which would be obtained if the wire were simply wound round a straight bar, and the bar then bent into a horse shoe shape On this account, as will be at once understood, the actions of the two poles of the magnet upon the two coils of wire, when presented to them, is conspiring to send a current in one direction through the wire On revolving these bobbins in front of the poles of the magnet, currents are caused to pass in the wire, first in one direction, and then in the other, as the magnetism of the soft iron core is induced and reversed

These currents, though powerful, would be of little use owing to their passing alternately in opposite directions, and in order to make them of practical value, an arrangement, called a *commutator*, whose object is alternately to reverse the connection of the bobbins with any wire or other interpolar through which it is desired to send the current, is employed The following will give a general idea of the commutator full descriptions, with diagrams, will be found in all the ordinary text-books on electricity The extremities of the wire coming from the bobbin, are brought to a cylinder of ivory or boxwood, which is a continuation of the axle on which the bobbins turn, and which turns with it, and on the circumference of this cylinder are two pairs of half rings of brass Each extremity of the wire is connected with one of the pairs of half rings There are two binding screws upon the case or frame of the machine to which any wire through which a current from it is to be passed may be attached, and from each of these screws a pair of springs proceeds to the ivory cylinder which we have just mentioned, and each spring presses during half a revolution upon a half ring, and during the other half revolution upon the ivory of the cylinder Thus, during half the revolution, each of them is put in connection with a wire of the bobbin, and during the other half it is insulated, touching only the ivory. Now,

the current is reversed at every half revolution, and since there are four springs and four half-rings, it will be easily understood that by properly arranging the positions of the half rings on the cylinder, one spring from each screw may press on its half ring when the current is going in one direction, and the other pair of springs on their respective half-rings when the current is going in the opposite direction, and that thus the connection, as far as any body attached to the binding screws is concerned, may be reversed at each reversal of the current, and that the current may thus be caused to pass always in the same direction through it

We have described a simple form of magneto-electric machine here Lately Siemens, Wilde, and Wheatstone have made enormous improvements in the construction of them, but for these we must refer the reader to more detailed works

MAGNETOMETER, BIFILAR See *Balance, Bifilar*

MAGNETOMETER, GAUSS'S, is a very delicate form of declinometer, or instrument for determining the angle which the plane of the magnetic meridian makes with the plane of the astronomical meridian, invented by Gauss A magnet bar is suspended by a fine silk fibre offering the least possible torsional resistance to the motion of the bar At the centre of the bar is fixed a light silvered mirror, looking in the direction of the length of the bar and turning with it The magnet is enclosed in a glass case to shield it from currents of air At a distance of several feet is placed a telescope with cross wires, and a scale at right angles to the axis of the telescope, the one is set a little above the mirror and the other a little below, and the divisions of the scale are reflected by the mirror into the telescope, and can be read off with great exactness by means of it The numbers on the scale, thus read off, are proportional to the tangent of twice the angle by which the needle has turned from zero If then the axis of the telescope is in the astronomical meridian, the angle so determined is the declination angle If not, it can easily be determined by calculation, from knowing the angle made by it with the astronomical meridian

MAGNIFYING POWER OF THE TELESCOPE See *Telescope, Magnifying Power of*

MALACHITE The mineralogical name of native carbonate of copper It is of a rich variegated green colour, and as it is susceptible of receiving a high polish, is much prized for ornamental purposes (See *Copper*)

MALLEABILITY (*Malleus*, a hammer) The property of extending under the blow of a hammer It is opposed to brittleness, and is almost restricted to metals Malleable substances must be tenacious, resisting fracture, and soft, permitting the particles to glide over one another The malleability of the most common metals is in the following order 1 gold, 2 silver, 3 copper, 4 platinum, 5 iron, 6 aluminium, 7 tin, 8 zinc, 9 lead Gold may be reduced to leaves of 1–180,000th of an inch in thickness, and weighing only 3 grains per square foot Leaf iron has been obtained 1-4800th of an inch in thickness, and weighing one-third of a grain per square inch Malleability is much influenced by temperature, the temperature of greatest malleability being different for different metals Iron is most malleable at a low white heat, in this state, therefore, it is welded or rolled into bars or plates

Although ductility and malleability are nearly allied, the same metal does not always possess both qualities in the same proportion Thus iron is nearly as ductile as gold, but far less malleable (See *Ductility, Hardness, Tenacity*)

MANGANESE A metallic element, compounds of which have been known from very early times, although it was not until 1774 that the metal was isolated by Gahn Atomic weight 55, symbol Mn, specific gravity 8 013 In the pure state manganese is a white brittle metal which melts only at the highest heat of a blast furnace It oxidises both in air and water, and dissolves easily in dilute mineral acids It is slightly magnetic

Manganese forms several oxides, the most important of which are the following —

The *protoxide* (MnO) This is obtained hydrated as a white precipitate on adding an alkali to a protosalt of manganese, it oxidises very readily It unites with acids to form a well-defined series of salts

Sesquioxide of Manganese (Mn_2O_3) This is met with native as *braunite* in opaque brownish black crystals, brittle and infusible In the hydrated state ($Mn_2O_3H_2O$), it is met with native as manganite or gray manganese ore, in dark steel gray crystals, which are fusible before the blowpipe

Manganoso-manganic oxide (Mn_3O_4). Known also as red oxide of manganese and Hausmannite It occurs in dark brown crystals of a submetallic lustre, opaque and infusible This oxide is easily obtained, as by ignition in the air lower oxides of manganese absorb oxygen, and higher oxides evolve oxygen, and are converted into this oxide

Peroxide of Manganese or dioxide (MnO_2) This is the most important oxide of manganese, it is met with native as pyrolusite, it forms bluish black metallic looking crystals of specific

gravity 4 9, opaque and infusible before the blowpipe It sometimes occurs massive Its great use in manufactures is as an oxidising agent, as it parts with some of its oxygen, and is reduced to the red oxide when exposed to heat It is largely used in the preparation of oxygen, in the manufacture of chlorine, and for decolourising glass

Under the names of psilomelane, varvesite, wad, &c , occur native oxides of manganese of no very definite constitution, but which appear to be mixtures of oxides previously described

Manganic Acid (H_2MnO_4) is not known in the separate state, but its compounds with bases are known under the name of *manganates* The only manganate of importance is the potassium salt (K_2MnO_4) This has long been known in the impure state under the name of *mineral chameleon*, a crude mass prepared by igniting chlorate of potash, caustic potash, and peroxide of manganese When this is dissolved in cold water, it forms a green solution which rapidly passes through several shades until it gets red The pure salt has been obtained in green crystals, which, however, decompose on addition of water into permanganate of potassium, caustic potash, and peroxide of manganese

Permanganic Acid ($HMnO_4$) This is the highest state of oxidation of the metal In the pure state it is a thick syrupy liquid of a greenish metallic lustre When gently heated it volatilises, forming violet vapours which condense without decomposition If the heat is not applied cautiously, it decomposes with explosion Permanganic acid is one of the most powerful oxidising agents known, instantly igniting some combustible bodies when added to them, and exploding with others It forms well defined salts with bases, of which, however, we need only mention the following —

Permanganate of Potassium ($KMnO_4$), crystallises in long deep red needles, which are permanent in the air and dissolve in about sixteen parts of cold water A solution of permanganate of potassium is of great use both in the laboratory, as a convenient oxidising agent and standard test liquid, and also as a harmless and powerful deodorising agent for household purposes

Permanganate of Silver ($AgMnO_4$), crystallises out when warm solutions of nitrate of silver and permanganate of potassium are mixed together It has been proposed to be used as an oxidising agent, epecially in some photographic operations

Chloride of Manganese ($MnCl_2$), is obtained in the hydrated form (with two atoms of water) by dissolving any oxide of manganese in hydrochloric acid, chlorine being given off, in the case of the higher oxides The solution, on evaporation, deposits pale rose coloured crystals, which are very soluble in water and alcohol, and on being strongly heated leave the anhydrous chloride It forms double salts with other chlorides

At the Liverpool meeting of the British Association held in September 1870, Mr J Fenwick Allen described several valuable alloys of manganese with copper, tin, zinc, and lead The simple alloy of manganese and copper containing from 5 to 30 per cent , is both malleable and ductile, with a tenacity considerably greater than that of copper The triple alloy of manganese, copper, and zinc closely resembles German silver When tin or lead is added to the alloy of manganese and copper, castings can be made which are eminently applicable as bearings for machinery

MANGANITE See *Manganese, Oxides*

MANNITE A sweet crystalline compound, prepared from manna, a juice exuding from some species of ash It crystallises in four sided prisms, which are easily soluble in water Composition $C_6H_{14}O_6$

MANOMETER (μανός, rare , μέτρον, a measure) An instrument for measuring the pressure, and thence the density of the air The form of manometer, usually used to verify Boyle's Law, is a bent tube like a siphon barometer, hermetically sealed at the end of the shorter leg A small quantity of mercury is poured into the tube so as to fill the bend, and thus to intercept communication between the air in the closed end and the external atmosphere When more mercury is poured in, the pressure on the enclosed air is equal to the atmospheric pressure *plus* that of the mercurial column in the longer leg, above the level in the shorter leg

MAPPING SPECTRA, BUNSEN'S METHOD OF Bunsen has described an excellent method of mapping spectra, so as to record, not only position, but likewise the peculiarities of breadth, sharpness, and intensity of colour of the different lines It is principally applicable to those spectra which consist of luminous bands, such as of the alkalies and alkaline earths The method consists in representing the luminous lines by black bands drawn on a graduated scale, their width denoting the width of the band, and their height the intensity, whilst the sharpness or nebulosity is denoted by the curved outline The positions of the lines are referred to the standard lines of potassium, lithium, sodium, and thallium (See Bunsen's paper in the *Phil Mag* , series 4, vol xxvi , p 247 , also Roscoe's *Spectrum Analysis*, p 88)

MARBLE. See *Carbon , Carbonate of Calcium*

MARCASITE See *Iron, Sulphides*

MARINE BAROMETER See *Barometer*

MARINE BOILER See *Steam Boiler*

MARINE GALVANOMETER See *Galvanometer*

MARINER'S COMPASS See *Compass, Mariner's*

MARGARIC ACID An artificial fatty acid of the formula $C_{17}H_{34}O_2$, prepared by the action of potash on cyanide of cetyl It forms white crystals, melting at 59 9° C, soluble in ether, insoluble in water, and uniting with bases to form salts The substance commonly called margaric acid has been shown by Heintz (Pogg Ann cii, 272) not to be a definite acid, but a mixture of palmitic, stearic, oleic acids, &c

MARIOTTE'S LAW See *Boyle's Law*

MARKAB (Arabic) The star α of the constellation Pegasus (See *Algenib*)

MARS In astronomy, the fourth planet in order of distance from the sun, and the superior planet whose orbit lies nearest to that of the earth The mean distance of Mars from the sun is 139,311,000 miles, his greatest, 152,304,000, his least, 126,318,000 Since the earth's mean distance is 91,430,000 miles, it follows that the distance of Mars from the earth varies from about 35,000,000 to about 244,000,000 miles His orbit is considerably eccentric, more so in fact than that of any planet in the solar system except Mercury The eccentricity is 0 093262, the inclination, 1° 51′ 5″ The diameter of Mars is about 4,400 miles His equator is inclined about 28 degrees to his orbit Mars completes his sidereal revolutions in a mean period of 686 9797 days, and returns to opposition at intervals separated by a mean period of 779 936 days, which is therefore the planet's mean synodical period

Mars is the planet whose surface we examine under the most favourable circumstances For although Venus approaches nearer to us than Mars, yet when she is at her nearest she is invisible, being concealed by the solar light But when Mars is at his nearest, or in opposition, he shines upon the background of the midnight sky It would seem also that besides this the real surface of Venus is usually, if not always, concealed by clouds The surface of Mars, on the other hand, though occasionally concealed in part by clouds, is yet well seen generally, as regards at least a part of his disc On this account it has been found possible to determine the period of his rotation on his axis—that is, of the Martial day—with an accuracy which we cannot hope to secure in the case of any other planet Cassini, who was one of the earliest to study the features of Mars, assigned to him a rotation period of 24h 40m, which is not far from the truth Later, Sir William Herschel attacked the same problem, but though his estimate was nearer to the truth than that of Cassini, yet he was not so successful in dealing with the rotation of Mars, as was usually the case with him in such matters He saw that a long period, including many rotations, was necessary for great accuracy, but in passing from bi-monthly periods to the bi annual period corresponding to the planet's synodical revolution, he unfortunately missed one complete rotation, so that the period of the planet came out nearly 2m too great His estimate was 24h 39m 25s Mädler attacked the problem more successfully, and by including all the rotations occurring during seven years, obtained a rotation period of 24h 37m 23 8s Later, Kaiser of Leyden carried the range of the rotations over a far longer period—viz, from the observations made by Huyghens to those made in recent times He thus obtained the period 24h 37m 22 6s Lastly, the present writer, by comparing observations made by Hooke so far back as 1666, with those made by Dawes in 1867, and by Browning in 1869 (the latter specially made for the purpose of this calculation), obtained the rotation period 24h 37m 22 735s, which may be regarded as within one hundredth part of a second of the true value

The surface of Mars has been carefully studied by many observers Cassini and Hooke took pictures of Mars in 1666 Maraldi observed the planet in 1720 Sir William Herschel made a series of observations between the years 1777 and 1783 In the years 1830 37, Messrs Beer and Mädler made many drawings of Mars, which are wonderfully exact, considering the small telescopic power employed by these observers Observations of the planet have also been made by Kunowski, De la Rue, Secchi, Phillips, Nasmyth, and others The observations made in 1864 by Mr Lockyer are even better, and are surpassed only by the drawings which we owe to Mr Dawes, who subjected the planet to a searching scrutiny during the oppositions which took place between the years 1855-1865 He entrusted to the present writer twenty nine of these drawings, from which the latter constructed a chart of Mars, giving names to the principal lands and seas From this chart Mr Browning has made a globe of the planet, and, by photographing the globe, he has obtained a series of interesting stereograms

From the appearance of Mars, there is every reason to believe that the so-called lands and seas are really continents and oceans, while patches of white light which are seen near the poles of the planet may be confidently regarded as indicating the existence of ice and snow, as in the

polar regions of our own earth The spectroscope has shown that the atmosphere of Mars contains the vapour of water, so that when we find variable masses of white light over parts of his surface, we may conclude that they are due to the presence of clouds in his atmosphere Another feature which has given rise to some difficulty seems explicable also in this way The parts of the disc near its edge are commonly brighter than the middle of the disc and Dr Zollner has been at some pains to explain this feature as due to peculiarities of the planet's surface. But when we notice that the lands and seas become indistinct near the edge of the disc, we are led to see that another explanation is needed, even if it were not altogether impossible to accept an explanation which requires, according to Zollner's own account, that the surface of Mars should be covered by irregularities having a slope of no less than 75° The peculiarity must belong to the atmosphere, not to the surface of Mars, and may probably indicate that the ordinary arrangement of the Martial clouds resembles that of our own cumulus clouds We know that, during a summer day, when the sky overhead shows great blue spaces between cumulus clouds, the sky near the horizon seems almost wholly covered by clouds, the reason being not that clouds are really spread more thickly over regions all round the observer than near him, but that the effect of foreshortening brings more clouds into view in a given portion of the heavens near the horizon than in a similar portion overhead Now, we deduce from this the simple principle, that lines drawn at right angles, or nearly so to the surface of a globe, surrounded by an atmosphere bearing such clouds as our *cumulus* clouds, are less likely to encounter a cloud than lines drawn at an acute angle to the surface Hence, if the clouds of Mars be generally *cumuli*, the lines of sight to the central parts of the disc of Mars will encounter fewer clouds within a given portion of the disc, than lines drawn to parts near the edge , for the former meet the surface of the planet nearly at a right angle, the latter meet his surface at an acute angle The contrary would be the case were the atmosphere of Mars loaded with *stratus* clouds We have thus a means of forming an opinion as to one important meteorological relation in the case of the ruddy planet It would be well worth the trouble to inquire whether the peculiar brightness of the edge of Mars's disc is to be regarded as a constant or variable phenomenon, and whether it is more marked in one hemisphere than in the other during the summer or winter of either Martial hemisphere

Mars approaches the earth so nearly during some oppositions as to afford a very trustworthy means of determining the solar parallax Since at such a time he is shining on a dark sky, it is easy to compare his distance from certain stars of known position, according as he is viewed either from northern or southern stations, or as he is seen at different hours when viewed from one and the same station The latter method, devised by M Airy, has some advantages over the former Both methods have been applied with considerable success by astronomers (See *Sun, Distance of the*)

On account of his proximity to the earth, also, Mars presents a gibbous aspect when he is in quadrature, at which time the line of sight from the earth is inclined at a very considerable angle to the line from the sun to Mars

MARSH GAS , or, *Light Carburetted Hydrogen* A gaseous hydro carbon frequently occurring in nature It is the fire damp of miners, and frequently rises from the earth in marshy districts Specific gravity, 0 557 It has neither taste, smell, nor colour, and has no action on test paper It is very slightly soluble in water When ignited, it burns with a pale white flame Composition, CH_4

MARSIC (Arabic) The star α of the constellation Hercules

MASS Mass is a term for the quantity of matter in a body In order to measure mass, we assume that the attraction of the earth on all particles of matter is the same, and is not dependent on the nature of the matter attracted This assumption seems to be justified by the fact that bodies of all kinds fall with equal velocity in the exhausted receiver of an air pump Hence we measure the mass of a body by its weight, and can only define the mass as a quantity proportional to the weight If, then, at the same spot on the earth's surface one body is twice as heavy as another, the mass of the first is twice that of the second Suppose, however, that the body be weighed by a spring balance at a certain place, and weighed again by the same instrument at another place nearer the equator, it will be found that the body is lighter at the latter place It is found also that the acceleration due to the attraction of the earth is also less at the second place than at the first, in the same proportion This illustrates the fact that when the mass remains the same, the weight varies as the acceleration of gravity Hence the weight varies as the product of the mass and the acceleration of gravity, and consequently when suitable units are chosen, the mass of a body is equal to its weight divided by the acceleration due to gravity (See *Laws of Motion*)

MASSICOT See *Lead, Oxides*

MASSON'S ELECTRO-PHOTOMETER. See *Electro-Photometer*.

MATTER, CONTINUITY OF THE LIQUID AND GASEOUS STATES OF Till within a little more than a year most people were taught to consider the liquid and gaseous conditions of matter as essentially distinct It has been long known, it is true, that many bodies could be obtained in the solid, liquid, and vaporous state, and that vapours approximately obey the law of Boyle Since 1823, the date of Faraday's communication to the Royal Society, it has been recognised that many bodies formerly considered to be gases, and only known in that state, could, by the application of cold and pressure, be reduced to liquids, and a few years later it was shown that some of these liquids are convertible into solids, but it was in 1869 that the beautiful researches of Dr Andrews threw an altogether new light on the subject of the connection of the liquid and gaseous state of matter

Suppose that at an ordinary temperature of the air, a quantity of carbonic acid gas be taken and exposed to pressure in a glass* tube, the following phenomena will be observed Suppose, for example, that the temperature at which the experiment is made is 0° C (32° F)' On applying pressure, the volume will be found to decrease, and were the gas a perfect one, it would decrease according to the well known law of Boyle, namely, that the volume of a gas varies inversely with the pressure, the temperature being kept constant Thus, if the pressure be doubled the volume is halved, and if the pressure be trebled the volume is reduced to one third But carbonic acid is not a perfect gas, and the volume diminishes much more rapidly than it should, according to the law just stated This divergence from Boyle's law increases as the pressure increases, till a pressure of 38 5 atmospheres is reached, when suddenly the law fails altogether, and without any further application of pressure the gas becomes a liquid What we have here described is true for all gases, with the exception of oxygen, hydrogen, nitrogen, carbonic oxide, nitric oxide, and marsh gas The pressure at which liquefaction takes place depends upon the nature of the gas, and upon its temperature Under *Liquefaction of Gases* will be found a table displaying this It is to be observed that the failure of Boyle's law is most apparent in the most easily condensed gases, the six that we have mentioned as not having been liquefied depart but little from it, and that the nearer the gas is to its point of condensation the more does it diverge from conformity to the law

The properties of the liquid carbonic acid are very remarkable Thilorier showed that the coefficient of expansion for heat of the liquid is greater than that of any aeriform body, and Andrews, that the compressibility of the liquid is much greater than that of ordinary liquids, and that it decreases with the pressure

If the experiment indicated above be tried with carbonic acid gas, at any temperature below 30° 92 C (87° 7 F), there will be a certain pressure, at which the abrupt transition from the gaseous to the liquid state takes place, but, in 1863, Andrews showed that above this temperature the case is very different He says—"On partially liquefying carbonic acid (that is, keeping the capillary tube mentioned in the note above in such a condition, by application of a proper amount of pressure, that the lower part may contain liquid carbonic acid, while that in the upper part is gaseous), by pressure, and gradually raising, at the same time, the temperature to 88° F, the surface of demarcation between the liquid and gas became faint, lost its curvature, and at last disappeared The space was then occupied by a homogeneous fluid, which exhibited, when the pressure was suddenly diminished, or the temperature slightly lowered, a peculiar appearance of moving or flickering striæ throughout its entire mass At temperatures above 88° no apparent liquefaction of carbonic acid, or separation into two distinct forms of matter, could be effected, even when a pressure of 300 or 400 atmospheres was applied Nitrous oxide gave analogous results" Or, again, if to gas above the temperature 30° 92 C pressure be applied, gradually increasing in amount, the volume of the gas will diminish steadily, but there will never at any point be an abrupt decrease of volume without any increased pressure such as that described in the first experiment "At 30° 92, and under a pressure of about 74 atmospheres, the densities of liquid and gaseous carbonic acid, as well as all their other physical properties, become absolutely identical, and the most careful observation fails to discover any heterogeneity at this or higher temperatures in carbonic acid, when its volume is so reduced as to occupy a space in which, at lower temperatures, a mixture of gas and liquid could have been formed In other words, all distinctions of state have disappeared, and the carbonic acid has become one homogeneous fluid, which cannot by change of pressure be separated into two distinct physical conditions This temperature of 30° 92 is called by Dr Andrews the *critical point* for carbonic acid Other fluids which can be obtained in both the liquid and gaseous states, have shown similar phenomena, and have each presented a critical point of temperature" †

* This is what Dr Andrews did The gas was contained in a fine thermometer tube, sealed at one end, and having a column of mercury to enclose the gas at the other Pressure was applied, and the mercury column driven into the tube, so as to diminish the volume of the gas the tube could be surrounded by a freezing mixture, and thus cold was applied (See *Liquefaction and Solidification of Gases*)

† Original Essay, by Prof James Thomson, LL D, "On the Continuity of the Gaseous and Liquid States of Matter"—*Nature*, 1870

Although, however, there is no *abrupt* change in the volume of carbonic acid when exposed to pressure at a temperature above the critical point, yet at temperatures near to this point the body possesses a peculiar property. At a certain pressure there is an excessively rapid deviation from Boyle's law; on the application of a pressure very slightly increasing, a diminution of volume quite disproportionate occurs. As the temperature is raised the peculiarity disappears; the law of Boyle is more nearly fulfilled till at a temperature of 48°·1 C., the application of a constantly increasing pressure gives rise to a perfectly gradual decrease of volume. In the paper of Dr Andrews (The Bakerian Lecture for 1869, Transactions of the Royal Society), the relation of volume to pressure at various temperatures is exhibited with the aid of carefully drawn curves, which display, in a way that no description can, the gradual alteration in elastic properties of carbonic acid as the temperature increases. We must refer our readers to that paper, and to the essay by Prof. James Thomson, quoted above, for many details.

In conclusion, we shall suppose the performance of two illustrative experiments of Dr Andrews. Let a volume of carbonic acid gas be taken, say at 50° C. (19° above the critical point), and let it be exposed to increasing pressure till 150 atmospheres have been reached. In this process its volume will steadily diminish as the pressure augments, and no sudden diminution of volume, without the application of external pressure, will occur at any stage of it. When the full pressure has been applied, let the temperature be allowed to fall till the carbonic acid has reached the ordinary temperature of the atmosphere. During the whole time no breach of continuity has occurred. It begins as a gas, and, by a series of gradual changes, presenting nowhere any abrupt alteration of volume or sudden evolution of heat, it ends as a liquid. That the gas has actually changed into a liquid would, indeed, never be suspected did it not show itself to be so changed, by entering into ebullition on the removal of pressure. Suppose, on the other hand, a volume of liquid carbonic acid kept by application of pressure from entering into ebullition, while the temperature is gradually raised to 50° C., it will steadily, if permitted to do so, expand, though without at any point exhibiting any sign of abrupt alteration. If, however, when its temperature has reached that point, the pressure be removed, it will be found that ebullition is no longer possible—that the liquid, in fact, has gradually become a gas.

Dr Andrews asks the important question, "What is the condition of carbonic acid when it passes at temperatures above 31° from the gaseous state down to the volume of a liquid without giving evidence at any part of liquefaction having occurred? Does it continue in the gaseous state, or does it liquefy, or have we to deal with a new condition of matter?"

He finds the answer in the recognition of the intimate relations which subsist between the gaseous and liquid conditions of matter. He looks upon the ordinary gaseous and liquid states only as widely separated forms of the same condition of matter, considering that the same body may be made to pass from one state to the other gradually, and without exhibiting any abrupt alteration. Under certain conditions of temperature and pressure, he says, carbonic acid finds itself, it is true, in a state of instability, and passes suddenly, with the evolution of heat and without the application of increased pressure or the decrease of temperature, from the gaseous to the liquid condition. But in other cases the distinction cannot be made, and it would be frequently impossible to assign to the carbonic acid one state rather than another.

MAUVEINE. See *Aniline*.

MAXIMUM DENSITY OF WATER. A remarkable exception to the general law of the expansion of matter by heat is presented in the case of water when near the freezing point. If we fill a thermometer tube with water, and place it side by side with a mercurial thermometer in a freezing mixture, we notice that the water (say at 60° F.) continues to contract until it reaches a temperature of 39·2° F. (4° C.); as the cooling continues it expands, and at 38° possesses sensibly the same volume as it did at 40·2°; the liquid expands until it reaches the freezing point, and at the moment of its conversion into ice a considerable expansion takes place. At 39·2° F. or 4° C. water therefore possesses its *maximum density*—that is to say, a vessel of a given capacity, say 1 cubic inch, will hold more water at this temperature than at any other. If the water be either cooled or heated when at this temperature it expands, and occupies greater bulk, and hence possesses less density. Supposing the water at 33° F., and that it is heated, we now obtain the curious anomaly of contraction produced by heat, and this will continue till it reaches 39·2°, when it will expand, and go on expanding till it attains 212° F., when it will become steam. Numerous experiments have been made with a view of determining the precise temperature at which water possesses its maximum density. According to Munke and Stampfer it is 38·8° F., while Blagdon made it 39°, and Hope and Rumford 40°. M. Despretz examined the question with extreme care, and fixed the temperature at 3·997° C., or 39·1946° F. The temperature which is now universally accepted is 4° C., or 39·2° F. The

following table shows the volume and density (or specific gravity) of water at various temperatures —

TABLE OF THE DENSITIES AND VOLUMES OF WATER AT TEMPERATURES VARYING FROM —9° C. (15 8° F) TO 100° C (212° F), ACCORDING TO M DESPRETZ. The volume and density at 4° C (39 2° F) = 1 000000

Temp	Volume	Density	Temp	Volume	Density
—9° C	1 0016311	0 998371	12° C	1 0004724	0 999527
—8	1 0013734	0 998628	13	1 0005862	0 999414
—7	1 0011354	0 998865	14	1 0007146	0 999285
—6	1 0009184	0 999082	15	1 0008751	0 999125
—5	1 0006987	0 999302	20	1 00179	0 998213
—4	1 0005619	0 999437	25	1 00293	0 997076
—3	1 0004222	0 999577	30	1 00433	0 995688
—2	1 0003077	0 999692	35	1 00593	0 994104
—1	1 0002138	0 999786	40	1 00773	0 992329
0	1 0001269	0 999873	45	1 00985	0 990246
1	1 0000730	0 999927	50	1 01205	0 988093
2	1 0000331	0 999966	55	1 01445	0 985756
3	1 0000083	0 999999	60	1 01698	0 983303
4	1 0000000	1 000000	65	1 01967	0 980709
5	1 0000082	0 999999	70	1 02255	0 977947
6	1 0000309	0 999969	75	1 02562	0 975018
7	1 0000708	0 999929	80	1 02885	0 971959
8	1 0001216	0 999878	85	1 03225	0 968757
9	1 0001879	0 999812	90	1 03566	0 965567
10	1 0002684	0 999731	95	1 03925	0 962232
11	1 0003598	0 999640	100	1 04315	0 958634

We notice above that the volume of water at several degrees below its freezing point has been given, and this arises from the fact that, under certain conditions, water may be cooled to a temperature many degrees below its freezing point without solidifying When water is deprived of air and cooled very slowly in a perfectly still place, it may attain a temperature of —6° C (21 2° F), and when cooled in a vacuum beneath a layer of oil the temperature has been reduced to —12° C (10 4° F) If, however, the vessel is agitated, the water instantly solidifies, and the temperature rises to 0° C (32° F) M Despretz has cooled water to —20° C (—4° F) without solidification

As water expands when cooled below 39 2° F, and also expands in freezing, it follows that ice is lighter than ice cold water M Brunner has determined the density of ice, and finds it to be 0 92013 at —19° C (—2 2° F), and 0 91800 at 0° C, from which he deduces 0 000122 as the coefficient of cubical expansion of ice for 1° C In virtue of its diminished specific gravity, ice floats upon ice cold water, and masses of water—inland seas, lakes, rivers, &c —can never be frozen into one mass of ice, as would be the case if ice, like other solids, were heavier than an equal bulk of the liquid which produces it As it is, the surface of water freezes first, and protects the water beneath it and the fish within it Let us imagine a lake at a temperature of 40° F in an atmosphere of 30° F, the surface is chilled to 39 2°, and the water at this temperature sinks at once to the bottom, while the warmer water rises and is chilled in its turn, until the whole mass of water has the same temperature As the cooling continues, the water reduced below 39 2 floats on the surface, and a layer of it is frozen If ice were heavier than ice cold water, lakes would freeze from below upwards, and would become one mass of ice, by which means all fish and other living things within them would be destroyed

We have mentioned above that water expands at the moment of freezing Now, the force of this expansion is enormous If a small quantity of water is securely enclosed in an iron bottle with sides an inch thick, and is then frozen, the bottle is broken To the same cause the bursting of water pipes during a sharp frost is to be traced The pipes are full of water at the time of the frost, and are broken when the water expands in becoming ice When the thaw commences the core of ice melts out of the pipes, and allows the escape of water through the fissures, so that, although the pipes are broken during the frost, we only become aware of the fact when the thaw takes place For the same reason, porous stones are cracked, and masses of fissured rocks are loosened and disintegrated during a hard frost Major Williams made the following experiment at Quebec, at a time when the temperature of the air was —28° C (—18 4° F) — He filled a bomb 35 centimetres (13 75 inches) in diameter with water, and closed it securely by an iron plug weighing three pounds At the moment when the water congealed, the plug was projected to a distance of more than 100 metres (328 feet), and at the same time a cylinder

of ice 22 centimetres (8 64 inches) long issued from the orifice of the bomb In a second experiment, the plug was not forced out, but the bomb broke, and a sheet of issued from the crack

MAXIMUM THERMOMETER A thermometer intended to indicate the highest temperature attained during a day, or during any given space of time *Rutherford's Maximum Thermometer* has a moveable steel index at the end of the mercurial column As the temperature rises, the mercury pushes this index before it, but when the temperature falls, the index does not follow the returning mercury The instrument is most conveniently set by bringing the steel index back to the mercury by means of a magnet In *Philip's Maximum Thermometer*, part of the mercurial column is separated from the rest by a minute air bubble, the detached part does not follow the mercury when the temperature falls In the maximum thermometer of Negretti and Zambra the tube is bent near the bulb, and the bore contracted at the angle Hence, when the temperature falls, the part of the mercury beyond the bend does not follow the retreat of the rest

MEAN DISTANCE In astronomy the mean distance of a planet is the mean between the greatest and least distances of the planet from the sun Thus the mean distance is equal to half the major axis of the orbit The extremities of the minor axis of an orbit are at the mean distance from the focus

MEAN SOLAR TIME See *Day*

MEASURES See *Metric System*

MEBSUTA (Arabic) The star ϵ of the constellation Gemini.

MECHANICAL ADVANTAGE The ratio between the power applied to a machine, and the weight or resistance supported by the action of a machine when just on the point of causing motion Thus if in a lever, having arms of 1 inch and 8 inches respectively, a power equal to 2 lbs applied at the long arm, keeps a weight of 16 lbs at the short arm at rest, the mechanical advantage of the lever is expressed by the ratio of 16 to 2, or 8 (See *Virtual Velocities*)

MECHANICAL EFFECT Work done by any agent, and estimated in terms of some unit of weight raised through a unit of height (See *Dynamical Unit, Foot-Pound, Horse Power*)

MECHANICAL EQUIVALENT OF HEAT A term introduced by Dr Julius Mayer of Heilbronn in 1842, to express the relationship existing between mechanical work and heat The mechanical equivalent of heat is the amount of actual visible force or work (usually measured in foot pounds or kilogrammetres) which is convertible into a unit of heat, and into which conversely a unit of heat can be converted The determination of the mechanical equivalent of heat forms the basis of the modern science of heat regarded as motion It was made quite independently by Dr Mayer, and by Dr Joule of Manchester, the former deducing his result by calculating the work done by a gas in expanding under certain conditions, while the latter worked experimentally, and proved the relationship between heat and work by direct mechanical and calorimetrical means We will first consider Mayer's method, as stated by Tyndall, and it is for the method, rather than for the result, that we are indebted to Mayer, because certain of his data were not perfectly correct A gas expands $\frac{1}{490}$ of its volume for 1° F, or $\frac{1}{273}$ of its volume for 1° C, hence a given volume will, on having its temperature raised 490° F, or 273° C, occupy twice as much space as before If we have a cubic foot of air at the freezing temperature of water, and under ordinary atmospheric pressure, and if we heat it until it doubles its volume, the heat which has produced this expansion will have performed a certain amount of work, for it will have caused the air to expand against the atmospheric pressure Now as the atmospheric pressure on a square inch of surface is in round numbers 15 lbs, it follows that the pressure on a square foot is $15 \times 144 = 2160$ pounds Therefore the heat, which has doubled the volume of the cubic foot of air, has raised 2160 lbs through a height of 1 foot The weight of a cubic foot of air at the freezing temperature is 1 29 ounces, and by a calculation relating to the specific heat, or capacity for heat, of a cubic foot of air compared with that of water, it is found that the amount of heat which has sufficed to raise the cubic foot of air through 490° F, or 273° C, would raise 0 31 oz of water through the same temperature, or 9½ lbs. of water 1° F, and 5 29 lbs 1° C Here, then, we have the data in terms of a unit of heat (which see), and the result may be stated as follows —The amount of heat competent to double the volume of a cubic foot of air under ordinary atmospheric pressure, and consequently by the means to lift 2160 lbs to a height of 1 foot, is equal to 9½ units of heat, (one pound of water raised 1° F), or to 5 29 units of heat, if we take as our unit 1 lb of water raised 1° C We now arrive at the second stage of the calculation It has been found that, when a gas is heated under a constant pressure (as in the above instance), it requires a larger amount of heat than when it is heated under a constant volume, in the former case, it is allowed to expand in the latter, the expansion is restrained. (See *Specific Heat*) The relation of these quantities

is as 1 42 to 1, or according to a recent determination as 1 414 to 1 Applying this to the heat absorbed by the cubic foot of air under constant pressure, we find the following proportion —

$$1\ 414 \quad 1 \quad 9\ 5 \quad x$$

$$\frac{1 \times 9\ 5}{1\ 414} \text{ units of heat} = 6\ 71 \text{ units.}$$

Or, in the case of the Centigrade unit—

$$1\ 414 \quad 1 \quad :: \quad 5\ 29 \quad : \quad x$$

$$\frac{1 \times 5\ 29}{1\ 414} = 3\ 74 \text{ units of heat}$$

Therefore, if the cubic foot of air had been heated under a constant volume—that is, if it had not been permitted to expand, and thus to cause an expenditure of force equal to 2160 pounds, raised to a height of one foot, it would have required 6 71 units of heat of the F scale, or 3 74 of the C scale

$$\text{Now } 9\ 5 - 6\ 71 = 2\ 79 \text{ Fahrenheit units,}$$
$$\text{and } 5\ 29 - 3\ 74 = 1\ 55 \text{ Centigrade units}$$

Therefore we find the excess of heat, imparted to the cubic foot of air, when allowed to expand, above that required to simply raise its temperature through 490° F or 273° C, is 2 79 units of the Fahrenheit scale, or 1 55 units of the Centigrade scale, and this excess has obviously lifted the weight of 2160 lbs through a height of 1 foot

$$\text{Hence } \frac{2160}{2\ 79} \text{ feet} = 774\ 1 \text{ ft}$$
$$\text{and } \frac{2160}{1\ 55} \text{ feet} = 1393\ 5 \text{ ft}$$

Therefore 1 unit of heat of the Fahrenheit scale is capable, when converted into mechanical work, of raising 1 lb weight to a height of 774 1 feet, or, what is the same thing, 774 1 lbs to a height of 1 foot, and 1 unit of heat of the Centigrade scale can, when transformed into mechanical work, raise 1 lb weight to a height of 1393 5 feet, or 1393 5 lbs to a height of one foot This is the mode of calculation adopted by Mayer, to determine the relation between heat and work—viz, the mechanical equivalent of heat

Mr Joule pursued an altogether different plan He sought to determine, by experimental means, the relation of the amount of mechanical work disappearing in the form of friction to the heat which resulted The simplest and most exact form of force which he could use, was that of a known weight falling through a known space, under the action of the force of gravity The laws of falling bodies (which see) are capable of, and have been submitted to, very exact determination and verification, and Mr Joule wisely chose a falling body as his source of mechanical power, the motion was communicated to a spindle, which was caused to revolve by the unwinding of string from it as the weight descended, on the principle of spinning a top, or giving rotatory motion to a gyroscope, and the spindle expended the motion thus received in producing friction in various ways, principally by causing a paddle to revolve in water and in mercury The paddle was inclosed in a circular vessel, carefully protected from receiving extraneous heat, and it contained water at a known temperature The heat, resulting from the friction of the paddle with the water, was measured with great accuracy by thermometers reading to $\frac{1}{200}$ of a degree Fahrenheit, and calculated according to ordinary calorimetrical methods, while every allowance was made for loss of mechanical power through friction of the pulleys, the spindle, and so on Joule's experiments were commenced in 1842, therefore simultaneously with Mayer's first calculations in the same direction In August 1843 Joule communicated his first results, and he continued the work for seven years, his principal and concluding determinations were published in the "Philosophical Transactions" for 1850, the paper bearing date, June 4, 1849

Mr Joule commences by giving a short historical account of the mechanical theory of heat. In the development of this theory, a law discovered by Dulong during his researches on specific heat, has been of the utmost importance, because it proves that, under certain definite conditions, the calorific effect is proportional to the work done The law may be stated as follows — "Equal volumes of all gases taken at the same temperature, and under the same pressure, being compressed or dilated to the same fraction of their volume, disengage or absorb the same *absolute quantity of heat*" (*Memoires de l'Académie des Sciences*, t 10, p 188) In 1842 Mayer stated that he raised the temperature of water by agitation from 12° to 13° C (53 6 to 55 4° F), but he did not mention the conditions of the experiment. In 1843 Mr Joule com-

municated to the *Philosophical Magazine*, a paper in which he announced that the temperature of water rises when it is forced through narrow tubes, and that 1 lb of water thus heated through 1° F requires the expenditure of an amount of mechanical force represented by 770 foot-pounds—that is, 770 lbs falling through 1 foot, or 1 lb falling through 770 feet In 1845 and 1847 he employed a paddle wheel in the manner above described, and obtained the numbers 781 5, 782 1, and 787 6, as the mechanical equivalent of heat, operating respectively with water, sperm oil, and mercury The experiments were made in a cellar which had the advantage of being subject to very slight changes of temperature, and the fall of the weights used to produce the rotation of the paddle was 63 inches The weights were either of 29 lbs, or of 10 lbs, and they were caused to fall 20 times—that is, the paddle was caused to revolve to the extent produced by the weights falling 20 times through 63 inches for each experiment, the temperature of the water in which the paddle revolved, being taken only at the commencement and termination of such 20 falls of the weights The velocity of the weights in descending was about 2 42 inches per second, and the time occupied by each experiment 35 minutes The following is a summary of the results obtained —

Number of Series	Number of Experiments	Material employed	Equivalent in Air	Equivalent in Vacuo	Mean
1	40	Water	773 640	772 692	772 692
2	20	Mercury	773 762	772 814	774 083
3	30	Mercury	776 303	775 352	
4	10	Cast iron	776 997	776 045	774 987
5	10	Cast iron	774 880	773 930	

"I consider," says Mr Joule, in concluding his paper, "that 772 692, the equivalent derived from the friction of water, is the most correct, both on account of the number of experiments tried, and the great capacity of the apparatus for heat And since, even in the friction of fluids, it was impossible entirely to avoid vibration, and the production of slight sound, it is probable that the above number is slightly in excess I will, therefore, conclude by considering it as demonstrated by the experiments contained in this paper —

"1 That the quantity of heat, produced by the friction of bodies, whether solid or liquid, is always proportionate to the force expended, and

"2 That the quantity of heat, capable of increasing the temperature of a pound of water (weighed in vacuo, and taken at between 55° and 60° F) by 1° F, requires for its evolution the expenditure of a mechanical force represented by the fall of 772 lbs through the space of 1 foot"

This is known as "Joule's equivalent," and is universally adopted If the unit of heat be taken as 1 lb of water raised 1° F, 772 foot-pounds represent the mechanical equivalent of heat, whereas, if the unit of heat be taken as 1 lb of water raised 1° C, 1389 6 foot pounds represent the mechanical equivalent of heat If Joule's equivalent is represented entirely by metric system numbers, the mechanical equivalent of heat is stated as 425 *kilogrammetres*—that is to say, the mechanical force necessary, when converted into heat, to raise the temperature of 1 kilogramme (2 2046215 lbs avoirdupois) of water, from 0° to 1° C (32° to 33 8° F), is represented by the fall of 425 kilogrammes through the space of 1 metre (3 2808992 feet), or 1 kilogramme through the space of 425 metres Conversely 1 calorie of heat, converted into mechanical work, would raise 1 kilogramme to a height of 425 metres (See also *Heat*, *Thermo-dynamics*, *Calorie*)

MECHANICAL VALUE OF LATENT HEAT See *Latent Heat*

MECHANICS (μηχανη, a machine) That branch of practical mathematics which considers the nature and laws of moving powers with their effect in machines, and the nature, generation, and communication of motion The science was divided by Newton into practical and rational mechanics, the former of which related to the mechanical powers, and the latter to the theory of motion It is usual now to divide mechanics into two divisions, the first treating of forces which keep the body or bodies on which they act at rest, and thence termed *statics*, and the second treating of motion The latter is subdivided into two parts, the first, termed *kinematics*, considers the properties of motion apart from the forces which produce it, and the second investigates the relation of the forces to the motion which they produce Both branches are frequently termed *dynamics*, although this term more properly belongs to the latter Mechanics, according to the ancient sense of the word, considered only the energy of *organa* or machines Although the practical uses of the simple machines were undoubtedly known to the ancients they were almost entirely ignorant of the theoretical principles of the science Vitruvius, in his tenth book, mentions several ingenious machines in which the inclined plane,

pully, and lever were used Archimedes was the first to explain the efficacy of these machines on true principles, in his treatise "De Æquiponderantibus," and the science remained almost as he had left it until the sixteenth century, when Stevinus, an engineer of the Low Countries, determined the force necessary to sustain a weight on an inclined plane He was led to the solution by the fact that when a chain passes over the top of an inclined plane so that a part rests on the plane and a part hangs vertically, there will be equilibrium if the two extremities are in the same horizontal line In 1592 Galileo wrote his *Della Scienza Meccanica* with a full explanation of the theories of the lever, inclined plane, and screw A few years later he added the theory of falling bodies and of the pendulum, and proved that the velocity of a falling body is uniformly accelerated Torricelli, the pupil of Galileo, besides other contributions to the science, proved the important thereom that "if there be any number of heavy bodies connected together, and so circumstanced that by their motion their centre of gravity can neither ascend nor descend, these bodies will remain at rest" Descartes next treated the subject systematically, but his theories of motion were to a great extent erroneous and unsound In 1668 the Royal Society recommended the collision of bodies as a subject for investigation, and received in response three papers, respectively by Huyghens, Wallis, and Wren Huyghens also determined the relation between the length and time of oscillation of a pendulum In 1687 Newton, in his Principia, separated the composition of forces from the composition of motion, and by applying the principles of fluxions laid the foundation of the modern system of theoretical mechanics Leibnitz made some improvements, employed the "Principle of Sufficient Reason," and clearly enunciated the law of continuity In 1686 he published in the Leipsic Journal "the demonstration of a great error, commenced by Descartes and others, in estimating the force of moving bodies" In this article it was stated that the force of a moving body did not vary as the velocity, but as the square of the velocity In the discussion which followed English mathematicians maintained that the force of a body of mass (m) and velocity (v) is proportional to mv, since when two bodies meet having these products equal their motion is destroyed, while the mathematicians of Germany, Italy, and Holland measured the force by mv^2 French mathematicians were divided, Maclaurin, Stirling, Desaguliers, Jurin, Clarke, and Marian taking the first view, and Bernoulli, Herman, and Muschenbroeck the second Both sides, however, always resolved the same problems in the same way, and arrived at the same results In 1743 D'Alembert showed that both views were true, and that the term force was used with different significations, the one referring to time and the other to space When a body is moving upwards against the force of the earth's attraction, the time during which it will rise is proportional to the square of the velocity If the force be referred to the *time* during which it will overcome a given resistance then it is proportional to v, but if to the *space* through which the resistance will be overcome then it is proportional to v^2 (See *Momentum*, and *Energy*)

The next important contribution to mechanics was the principle of the conservation of living forces (*vires vivæ*) established by J Bernoulli In 1788 Lagrange applied the method of co-ordinates, and thus made the science purely analytical

The best complete treatises on the subject are Poisson's *Traité de Mécanique*, and Thomson and Tait's *Natural Philosophy*

MEDIUM, RESISTING A diffused ethereal matter supposed to occupy the inter-planetary and inter-stellar spaces, resisting the motions of all bodies and perceptibly modifying the motions of such bodies as comets

MEGASCOPE (μεγας, great, and σκοπεω, to see) An instrument for taking magnified drawings of objects It is the same in principle as the *Solar Microscope* and *Magic Lantern*

MELODY A succession of single sounds That branch of the musical art which treats of the relation of sounds produced in succession

Sounds used in Melody The series of sounds used in music are thus related —Let us take a sound as that, for instance, which is produced by 512 vibrations per second as a fixed sound for reference, then let us obtain the sound made by twice this number, or 1024 vibrations per second The second sound is termed the octave of the first By dividing the interval between these sounds into six equal parts, we obtain *six tones*, and, by dividing it into twelve equal parts, we have *twelve mean semitones* included by thirteen sounds Similarly, any other octave contains twelve mean semitones If from the thirteen sounds including the octave, we strike out the 2d, 4th, 7th, 9th, and 11th, the sounds remaining form what is termed the *major scale* If we strike out the 2d, 5th, 7th, 10th, and 11th, we obtain the *minor scale* In the major scale the interval between the first and third notes is a *major* third, and in the minor scale this interval is a *minor* third (See *Musical Interval*)

These two scales, which, from their intervals consisting *chiefly of tones*, are both included under the term *Diatonic Scale*, form the source or fountain head of all modern music, the major scale supplying us with expressions of a joyful or triumphant character, the minor with strains

of plaintiveness and sorrow The major and minor scales are also spoken of as modes of the Diatonic Scale It will be observed that in the minor scale series, as above indicated, there is an interval of *three semitones* between its sixth and seventh sounds This interval being an extreme one, is avoided in melody by *raising the sixth* a semitone in ascending passages, and by *lowering the seventh* in descending passages

In contradistinction to the Diatonic Scale, the scale or series of mean semitones is called the *Chromatic Scale*

Names of the Sounds The sounds of the major scale are named by the first seven letters of the alphabet, C, D, E, F, G, A, B These letters were first used in the Æolian scale, which resembled our minor scale, and the first sound of which was called A A better knowledge of the harmonic relations of the sounds has led to the major scale on C being chosen as the normal scale, nevertheless, the Æolic letters have been retained, thus making C instead of A the first sound of the normal scale The other sounds are named by means of the same letters with chromatic signs (♯ and ♭), to show that they are to be considered as elevations or depressions of the sounds adjacent to them

	Name	Major Scale of C	Minor Scale of C
1	C′	C	C
12	B	B	B
11	B ♭ or A ♯, B flat or A sharp		
10	A	A	
9	A ♭ or G ♯, A flat or G sharp		A ♭
8	G	G	G
7	G ♭ or F ♯, G flat or F sharp		
6	F	F	F
5	E	E	
4	E ♭ or D ♯, E flat or D sharp		E ♭
3	D	D	D
2	D ♭ or C ♯, D flat or C sharp		
1	C	C	C

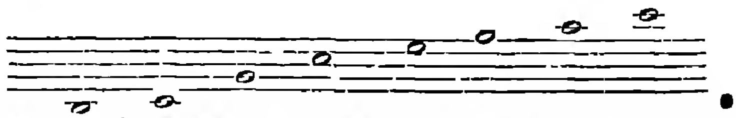
Sounds take the same letter names as their octaves The sound made by 512 vibrations per second is *middle* C, by 1024, *upper* C, by 2048, C in *alt*, by 4096, C in *altissimo*, by 256, *lower* C, by 128, *contra* or *double* C

Amongst vocalists, seven Italian syllables are also used to name the sounds of the musical scale

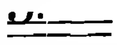
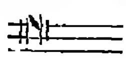
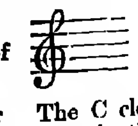
1	2	3	4	5	6	7	8
Do	Re	Mi	Fa	Sol	La	Si	Do

Pitch The relative height of a sound is termed its *pitch* The pitch depends on the number of vibrations per second which produce the sound, the greater the number of vibrations per second, the higher being the pitch

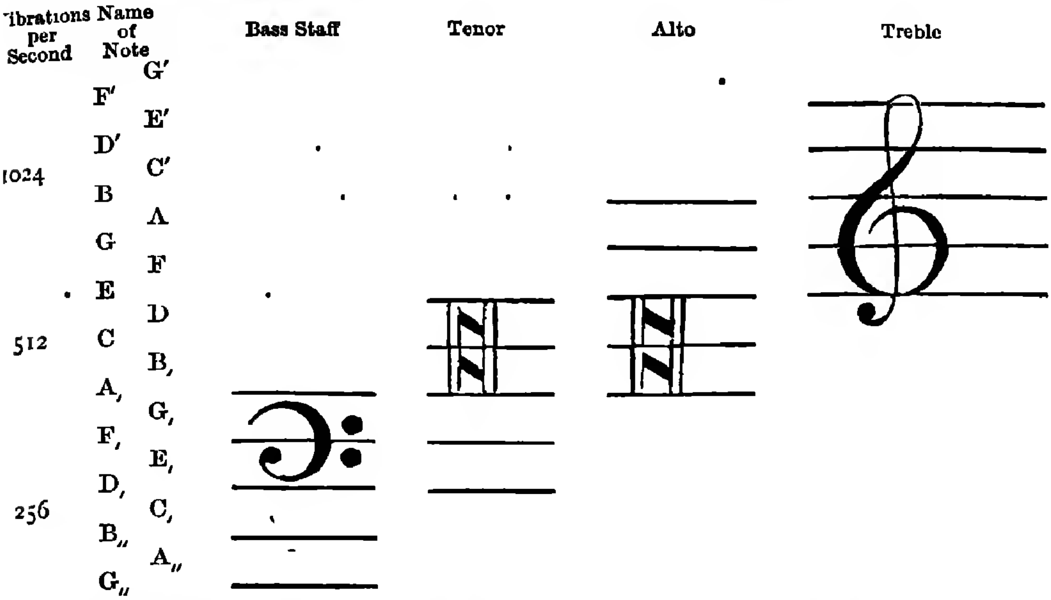
The Staff To denote differences of pitch, five equidistant parallel lines are used, forming what is termed the staff Symbols, termed notes, are placed on the staff in different positions to denote sounds of different pitch The staff, with its five lines and six spaces, will represent eleven sounds Sounds above or below these are represented by adding small lines, termed *leger* lines, thus—



Clef The staff of five lines is sufficient for a melody written for an individual voice, but parts for different voices are written on staves which represent sounds, from different parts of the series of musical sounds A sign termed a *clef* is placed on one of the five lines to show what sound is represented on that line There are three clefs in use

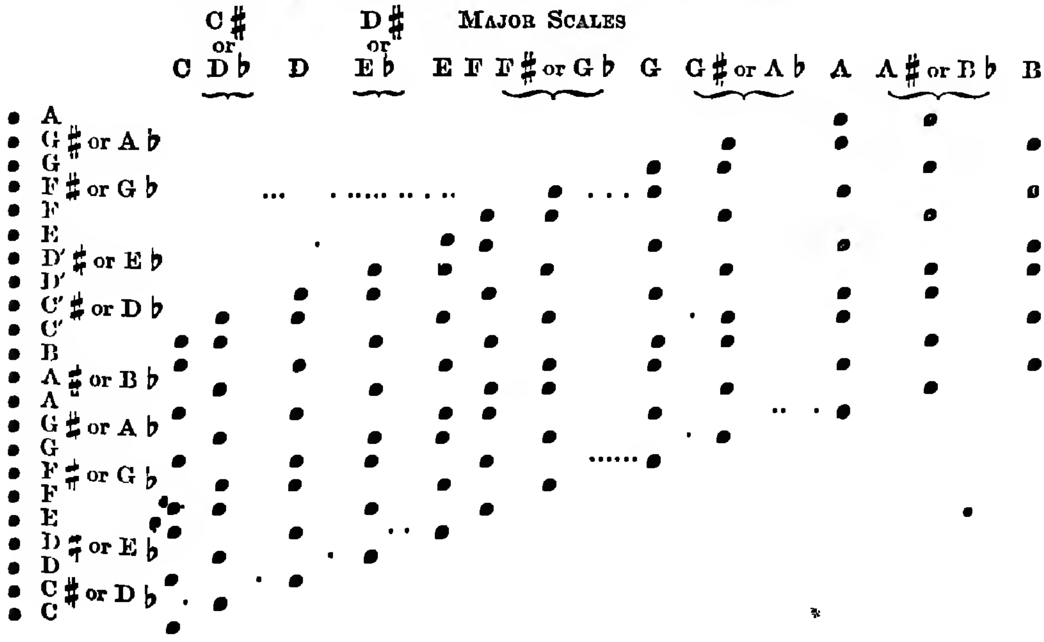
1 The F Clef,  2 The C Clef  3. The G Clef 

The following figure shows the relation of the various staves to one another The C clef, which is here introduced for the two voices Tenor and Alto, is frequently dispensed with, the sounds of these voices being written upon the Treble Staff, and those of the tenor appearing an octave higher than they are to be sung



Range of the Human Voice The ordinary range of women's and boy's voices is in the treble of soprano (*supremus*, highest), from C (512 vib.) to G′ or A, in the alto or contralto from G, to C′ or D′. The compass of men's voices is usually in the tenor, from C, (256 vib.) to G (tenor, from *teneo*, to hold), the *leading* voice so called, because in mediæval tunes this voice sustained the leading melody. The alto (*altus*, high) was so named because it was higher than the leading voice, and in the bass from G,, to D. These limits, however, are often very much exceeded by solo singers. In 1770, Mozart heard Bastardella at Parma close a cadenza with C‴ (C in *altissimo*, or C of 4096 vibrations per second). In his Twelfth Mass also the same composer carried the bass to G, to display the voice of a celebrated singer of his day. Signor Lablache, the late basso-profundo, could sustain with ease and power C,, (double C, or C of 128 vib.)

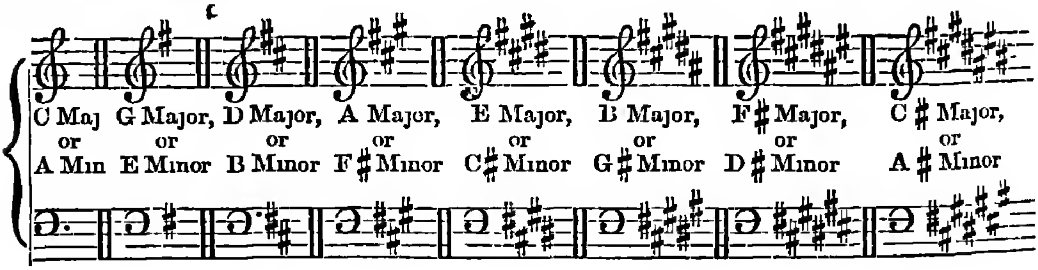
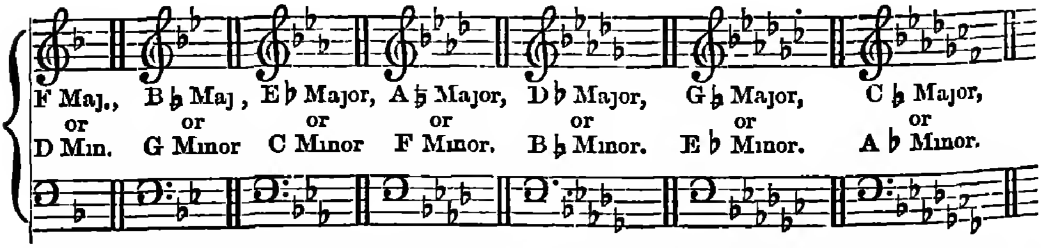
Signatures Scales may be founded on any one of the twelve sounds which occur in an octave. The fundamental sound or key note gives its name to the scale. This key sound is also called the *tonic* of the scale.



From the above Table it will be seen that the Scale of

G	requires	one sharp,	namely,	F ♯
D	"	two sharps,	"	F ♯ and C ♯
A	"	three "	"	F ♯, C ♯, and G ♯
E	"	four "	"	F ♯, C ♯, G ♯, and D ♯
B	"	five "	"	F ♯, C ♯, G ♯, D ♯, and A ♯
F ♯	"	six "	"	F ♯, C ♯, G ♯, D ♯, A ♯, and E ♯
C ♯	"	seven "	"	F ♯, C ♯, G ♯, D ♯, A ♯, E ♯, and B ♯
F	"	one flat,	"	B ♭
B ♭	"	two flats,	"	B ♭ and E ♭
E ♭	"	three "	"	B ♭, E ♭, and A ♭
A ♭	"	four "	"	B ♭, E ♭, A ♭, and D ♭
D ♭	"	five "	"	B ♭, E ♭, A ♭, D ♭, and G ♭
G ♭	"	six "	"	B ♭, E ♭, A ♭, D ♭, G ♭, and C ♭
C ♭	"	seven "	"	B ♭, E ♭, A ♭, D ♭, G ♭, C ♭, and F ♭

In the same way minor scales may be founded on each of the sounds of the chromatic scale by writing out all the sounds of the octave from the fundamental note, and rejecting the 2d, 5th, 7th, 10th, and 11th

Instead of writing the chromatic signs (♯, ♭) on the staff with the notes as they occur, they are usually written at the commencement of the piece, and form what is termed the key signature The same signature is used for a major scale, and for its relative minor, *i e*, the minor scale most nearly related to it. The following is a table of the signatures as they appear on the treble and bass staves.—



All sounds introduced into a melody which are not in the scale in which it is commenced are accompanied by their chromatic signs, which are then termed *accidentals*. The effect of a sharp or a flat is removed by a *natural* ♮.

Duration The duration of musical sounds may be considered relatively or absolutely. Relative duration is indicated by the shapes of the notes, thus—

Note.	Breve.	Semibreve.	Minim.	Crotchet.	Quaver.	Semiquaver	Demi-Semiquaver
Ratios of No in a given time.	½	1	2	4	8	16	32
Ratios of duration.	64	32	16	8	4	2	1

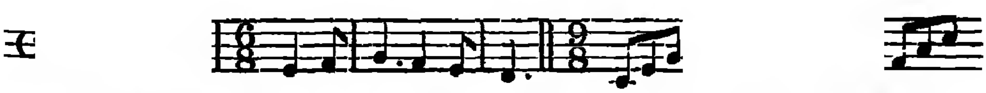
Notes of intermediate duration are formed by placing a *dot* after a note, thus making it half as long again, or a *double dot*, the second dot having half the value of the first, or by grouping notes of various lengths by the *slur or tie* ⌒.

Rests, or notes of silence, correspond in duration to notes of sound, thus—

Absolute duration is expressed approximately by the Italian terms, *adagio*, very slow, *andante*, slow, *moderato*, moderate, *allegro*, quick, *presto*, very quick, and a number of terms with intermediate significations. Exact indication is afforded by means of the metronome, an instrument invented by Maelzel, a German mechanician, and consisting of a pendulum, the time of oscillation of which may be varied at pleasure by means of a moveable index and a scale which shows the number of oscillations per minute The indication M 𝅗𝅥 = 60 attached to a composition, shows that when the regulator of the pendulum in Maelzel's metronome is at 60, each oscillation represents the duration of a minim *Rhythm* The recurrence of stress in a melody at regular intervals of duration is called *rhythm*, the stress itself being termed *accent*. The position of the accents is indicated by drawing vertical lines across the staff so that the accented notes shall occur immediately after the lines The lines are termed *bars*, and the part of the melody between two bars, that is, between two equally accented notes, is termed a *measure* In the same melody all the measures are of the same duration Although the measures themselves indicate the rhythm, a mark is usually placed after the clef for this purpose, consisting of a fraction the denominator of which shows into how many parts the semibreve is divided, and the numerator how many of these parts are contained in a measure Thus of simple measures we have in *duple* rhythm $\frac{2}{2}$ (read two-two) $\frac{2}{4}$ and $\frac{2}{8}$, and in *triple* rhythm $\frac{3}{2}$ $\frac{3}{4}$ and $\frac{3}{8}$ measure, of compound measures we have in *duple* rhythm $\frac{6}{4}$ and $\frac{4}{4}$ (also termed common) and in triple rhythm $\frac{9}{4}$, $\frac{9}{8}$, $\frac{6}{4}$ and $\frac{6}{8}$ measure In the compound measures, in addition to the principal accent on the first note of the measure there is a subordinate accent on the first note of each subdivision of the measure.

Simple Measures.

Compound Measures



Grouping of Measures. Every melody may be divided into groups of measures termed *phrases*, each having a distinctive character. By taking a larger number of measures, the melody is divided into *strains* or *periods*, having more strongly marked terminations or cadences.

Common Forms of Melody. The single chant is a melody of one strain not strictly rhythmical, but suited for the intoning of the prose of Psalms. The double chant consists of two such strains. The majority of Psalm, Hymn, and sacred and secular song tunes are pieces of two strains The rhythmical structure of Psalm and Hymn tunes depends on the metre of the poetry to which they are set. A *long measure* hymn consists of four-line stanzas with four iambic feet or eight syllables in each line, *common measure* consists of four lines with four and three iambic feet—eight and six syllables—alternately. Short measure has two lines with three iambic feet, then a line with four feet, and then a fourth with three feet. A *sevens*

hymn has stanzas of four lines of seven syllables, alternate syllables, beginning with the first, being accented. For the names of intervals, and the relation between the intervals of musical practice and those derived from the theory of sound (see *Musical Interval*), and for the relation of sounds simultaneously produced see *Harmony*

MENISCUS LENS (μηνισκος, a little crescent) A lens having one convex and one concave surface, the convexity exceeding the concavity. It acts as a convex lens, bringing incident parallel rays of light to a focus.

MENISCUS PRISM See *Prismatic Lens*

MENKALINAN (Arabic) The star β of the constellation Auriga

MENKAR (Arabic) The star α of the constellation Cetus

MENOTTI'S BATTERY is a Daniell's battery in which the porous cell is replaced by a layer of wet sawdust or sand. It is already much used for telegraphic purposes, being admirable for its constancy and for the ease and cheapness of construction In the Menotti cell, a thin copper-plate, to which is soldered a gutta-percha covered copper wire, is laid at the bottom of a convenient jar, the wire projecting out of it Over this is placed a layer of sulphate of copper an inch or two thick, and then three or four inches of sawdust which has been well soaked in water A thick circular plate of zinc placed on the top, having a wire soldered to it, completes the cell, and by its weight keeps the sawdust and sulphate of copper well pressed down Frequently an inch of water is kept over the zinc plate to preserve the wetness of the sawdust and thus diminish the internal resistance The current proceeds from the zinc through the cell to the copper, and the chemical action is exactly the same as in the Daniell's battery, sulphate of zinc being formed and metallic copper deposited

MENSA. (Abbreviated for Mons Mensæ, the *Table Mountain*) A small southern constellation formed by Lacaille.

MERCURY. In astronomy the planet nearest to the sun Mercury's mean distance from the sun is 35,392,000 miles, his greatest 42,669,000, his least 28,115,000 As the earth's mean distance from the sun is 91,430,000 miles, it follows that Mercury's distance from the earth varies between about 45,000,000 and about 135,500,000 miles He is most favourably seen when nearly at his greatest elongation, at a distance of about 85,000,000 miles from us, when he appears as a half disc His mean sidereal revolution is completed in 87 9693 days, while the mean interval separating his successive returns to inferior conjunction is 115 877 days, so that he passes through all his phases more than three times in the course of every year His orbit is more eccentric and inclined at a greater angle to the ecliptic than that of any other planet, the eccentricity being no less than 0 205618, the inclination $7^\circ\ 0'\ 8\ 2''$ His diameter is estimated at about 3050 miles, his volume 0 058, the earth's being unity, his density one-tenth greater than the earth's, and his mass 0 065, the earth's being unity

Mercury is examined under very unfavourable circumstances by the telescopist, on account of its great proximity to the sun Thus we have little satisfactory evidence respecting his physical habitudes It is even doubtful whether the period of rotation assigned to Mercury (24h 5m 28s) can be regarded as satisfactorily established, and certainly very little reliance can be placed on the values which have been assigned to the inclination of the planet's equator plane

Since Mercury travels nearer to the sun than the earth, he is sometimes seen to pass over the sun's disc A phenomenon of this sort, though far less important than a transit of Venus, is yet not without interest to the astronomer In particular, it affords him the means of justly estimating the nature of those peculiarities which characterise all transits During the last transit of Mercury, for example, astronomers paid great attention to the appearance presented by Mercury when just about to leave the sun's disc (internal contact) The formation of the small black ligament which seems for a few seconds to connect the disc of Mercury with the outline of the solar disc, was found to be a phenomenon depending on the power of the telescope made use of, a conclusion of the utmost importance in connection with the approaching transits of Venus (See *Monthly Notices of the Royal Astronomical Society*, vols 29, 30) Transits of Mercury take place at intervals of 13, 7, 10, 3, 10, 3, &c, years (See *Planet*)

MERCURY. A beautiful white metal, liquid at the ordinary temperature Atomic weight, 200. Symbol, Hg, from its Latin name *Hydrargyrum*, ὕδωρ, ἄργυρον, liquid silver, or *quicksilver*. It was known to the ancients, and is frequently found native, it is usually obtained from the sulphide, which, when heated with lime in an iron or clay distillatory apparatus, is decomposed with liberation of the mercury which volatilises and sulphur which is retained by the lime Mercury does not oxidise at common temperatures, but near its boiling point it unites with oxygen. It boils at 360° C. (680° F.), forming a colourless vapour of specific gravity, 6 7. At $-39\ 44^\circ$ C. (-39° F) it solidifies with contraction to a tin white, ductile and malleable metal. At the ordinary temperature its specific gravity is 13 596. Vapour rises from it even at the freezing

point of water in sufficient quantity to whiten gold leaf. It dissolves in hot nitric and sulphuric acids The following are the most important compounds of mercury —

Oxides of Mercury Mercury forms two oxides, the black oxide and the red oxide

Black Oxide of Mercury, called also suboxide or *Mercurous Oxide* (Hg_2O), is an almost black powder, easily decomposed by light, heat, or reducing agents, into oxygen and mercury It forms a well-defined series of salts, which are described under the headings of the acids.

Red Oxide of Mercury, or mercuric oxide (HgO), known also as binoxide of mercury and *Red Precipitate*, is usually prepared by igniting the nitrate of mercury, it is a crystalline, brick red, scaly powder, which is decomposed by heat into oxygen and mercury, and also by light superficially It is very slightly soluble in water, but sufficiently so to give it a metallic taste and alkaline reaction Reducing agents convert it either into the black oxide or into metallic mercury It dissolves in acids forming salts, the most important of which are described under the headings of the respective acids

Sulphide of Mercury *Mercuric Sulphide* (HgS), known also as *Cinnabar* and *Vermillion*. When prepared by precipitation this is a black amorphous powder, but it can be changed by judicious treatment into the red modification Native cinnabar is the principal source of mercury, it is of a scarlet colour, somewhat transparent and crystallises in rhombohedrons. When heated cinnabar gets brown, and black, and volatilises, recovering its beautiful colour on condensation and cooling Its specific gravity is 8 1

Chlorides of Mercury Mercury forms two chlorides, both of which are of importance.

Subchloride of Mercury, or Calomel (HgCl), also called mercurous chloride, protochloride of mercury, is a dingy white heavy powder, tasteless, inodorous, and insoluble in water, it is volatile below redness, crystallises in prisms, and its specific gravity is 7 14

Perchloride of Mercury, or Corrosive Sublimate ($HgCl_2$), known also as mercuric chloride. This is a white semi-transparent crystalline compound, of specific gravity 5 42 When heated to 265° C (509° F) it melts, and at 295° C (563° F) boils It is soluble in water, alcohol, and ether When a solution of mercuric chloride is mixed with ammonia a bulky white insoluble precipitate is formed, known in pharmacy under the name of *white precipitate* Its chemical composition is HgH_2NCl, and it is called amido chloride of mercury, or chloride of dimercurammonium

Iodide of Mercury *Mercuric Iodide* (HgI_2) This is a brilliant scarlet powder which turns yellow when gently heated, but gradually recovers its scarlet colour, and instantly when rubbed. It is almost insoluble in water, but readily so in solutions of iodide of potassium, its specific gravity is 6 3

MERCURY, FULMINATING See *Fulminic Acid*

MERIDIAN (*Meridies*, mid-day) In astronomy, a great circle of the celestial sphere passing through the poles of the heavens and the north and south points of the horizon

MERIDIAN ALTITUDE. The meridian altitude of a celestial object is its altitude when upon the meridian

MERIDIAN, BRASS. The brass ring within which a globe is suspended, and within which it revolves

MERIDIAN MARK A mark placed at a convenient spot several miles from an observatory, and due south of the place of the transit instrument, to serve as a means of marking the direction of the true south point of the horizon.

MESARTIM Arabic. The star γ of the constellation Aries. It is a well known double, and said to have been the first recognised star of that kind

METACENTRE The metacentre of a floating body is the point, the position of which, in regard to the centre of gravity of the body, determines whether the body is in stable or instable equilibrium A floating body is kept at rest by two forces (see *Displacement*), one of which is its weight, and the other is a force equal to the weight of the water displaced. The first of these acts vertically downwards, and may be supposed to act at the centre of gravity of the body The second acts vertically upwards, and may be supposed to act at the centre of gravity of the space (filled with homogeneous matter) displaced by the floating body If these two points are in the same vertical line, it is clear that there must be equilibrium, and there can only be equilibrium when such is the case. Let the vertical line joining these two points, when the body is at rest, be called the axis of the body Suppose the body to be displaced, the position of the centre of gravity of the body, with regard to the body, remains unchanged, but the centre of gravity of the displaced water is changed in position with regard to the body A vertical line drawn through the centre of displacement will cut the axis The point of intersection is called the metacentre When the metacentre is higher than the centre of gravity of the body, the equilibrium of the body is stable, that is, the body will recover from a slight displacement. If the centre of gravity is higher than the metacentre, the body will roll over.

METALLIC RAYS, WAVE LENGTH OF. Thalén has published (*Nova Acta Reg Soc Scient Upsaliensis*, Series Tertia, vol vi., fasc. 2) an extended memoir on the wave lengths of the spectral lines of the elements. The author's work does not present any new measurements, but is based upon those made by Angstrom, which had already been employed for the purpose of interpolation by Dr. W Gibbs The method of proceeding was, however, new Each luminous ray, the wave length of which was to be measured, was in the first place entered either upon Kirchhoff's chart, which extends from A to G, or upon a new chart by Angstrom and Thalén, extending from G to H These rays were then transferred to the normal plates of the spectrum furnished by Angstrom, and finally were entered upon the charts published with Thalén's memoir, each being placed according to its wave length In some cases the graphical method was employed The description of the process employed in determining the wave length is by no means clear The spectroscope used was provided with large telescopes, and with a prism of bisulphide of carbon, with a refracting angle of 60′ The number of elements examined amounted to 45, of these 23 were in the metallic state, the others being in the form of chloride One important result obtained by the author is the proof that the sun's atmosphere contains titanium The following elements had not before been examined with the spectroscope, glucinum, zirconium, erbium, yttrium, thorium, uranium, titanium, tungsten, molybdenum, and vanadium Appended to Thalén's memoir is a chart, in which the spectra of the different elements are entered upon the plan first employed by Mr Huggins, so that all the spectra are upon one sheet, with the normal spectrum at the top It must be borne in mind, however, that the lines upon Thalén's map are entered according to their wave lengths, and not upon an arbitrary scale. The memoir contains also a complete table of the wave lengths of all the lines of the elements examined

METALLIC REFLECTION Common light reflected from metallic surfaces becomes polarised elliptically, provided a sufficient number of reflections take place If plane polarised light is used it becomes elliptic by a single reflection from a metallic surface at an angle differing with each metal. Sir David Brewster gives the following list (*Optics*, p 230) —

Name of Metal	Angle of Maximum Polarisation	Name of Metal	Angle of Maximum Polarisation
Grain Tin,	78° 30′	Steel,	75° 0′
Mercury,	78 27	Bismuth,	74 50
Galena,	78 10	Pure Silver,	73 0
Iron Pyrites,	77 30	Zinc,	72 30
Gray Cobalt,	76 56	Tin Plate (hammered),	70 50
Speculum Metal,	76 0	Jewellers' Gold,	70 45
Antimony (melted),	75 25		

METALLIC THERMOMETER The best known of these instruments was invented by Abraham Breguet, and is based on the unequal expansion of different metals for the same increment of heat Three thin strips respectively of silver, gold, and platinum are soldered together, and coiled into a spiral, so that the silver forms the interior surface, and the platinum the exterior One end of the spiral is fixed, and a needle, which moves round a graduated arc, is attached to the other end Now, silver being the most expansible metal of the three, causes the spiral, when it is heated, to unwind itself, and this motion is registered by the index, similarly, when the temperature sinks, the spiral contracts and the index moves in the contrary direction The strip of gold is placed between the platinum and silver, so as to lessen their mutual effect, as if two metals of such different expansibilities as silver and platinum were placed in contact, it is probable that the strain would produce rupture This instrument, which is usually called *Breguet's Helix*, is graduated by means of an ordinary mercurial thermometer Metallic thermometers are sometimes formed of a compound band of steel and brass, which gives motion to an index by means of levers In the meteorograph of Father Secchi the temperature is indicated by the expansion of a brass wire seventeen metres in length, the motion being conveyed and multiplied by a system of levers (See also *Expansion*)

METALLOIDS See *Metals* and *Non-Metals*

METALS AND NON-METALS The elements are broadly divided into two classes, metals and non-metals, which merge, by almost insensible gradations, one into the other, so that it is impossible to give any definition of a metal which will not, in some way, either include substances decidedly non-metallic or exclude some metallic bodies A metal is usually supposed to be heavy, solid, opaque, malleable, ductile, tenacious ; to possess good conducting power for heat and electricity, and to have a peculiar lustre, known as the metallic lustre But very few metals possess all these properties, whilst some bodies, which are decidedly non-metallic, possess many of them. Thus, as far as density is concerned, the alkali metals are

lighter than water Mercury is only solid at a very low temperature Opacity is probably dependent only on mass, as Faraday has prepared films of gold, platinum, and other metals so thin as to be almost as transparent as glass Malleability is by no means a general property, and is especially absent in those metals which are approaching the non-metallic group in chemical properties, such as antimony, arsenic, and bismuth Many metals, such as lead and tin, have the properties of ductility and tenacity in a very inferior degree, whilst in antimony, arsenic, and bismuth they are entirely absent The conducting power for heat and electricity varies through a very wide range, and is possessed by some forms of carbon in a much higher degree than it is by certain metals All metals possess the metallic lustre, but this is also shared by some forms of carbon, by iodine, frozen bromine, selenium, and tellurium, which latter is, however, one of the conducting links between metals and non-metals The basic properties of many metallic oxides is strongly marked, but in others, such as gold, tungsten, molybdenum, it is very faint, whilst in arsenic and tellurium it is absent, and their oxides possess powerfully acid characters The fusibility of metals is almost universal, although the limits are the widest conceivable, ranging between a temperature much below zero to the highest artificial temperature producible In the case of osmium, which has never yet been liquefied, it is probable that a higher temperature would have the desired effect Arsenic, however, volatilises before liquefying, passing direct from the solid to the gaseous state From the above it is seen that, whilst there can be no doubt whatever about the position occupied by well defined metals, such as iron, copper, silver, thallium, lead, &c, and the non metallic character of sulphur, nitrogen, and chlorine, when we take some of the intermediate bodies we find their properties verge one into the other in such a manner that it is impossible to draw a sharp line of distinction between metallic and non metallic bodies The following table gives the metallic elements at present known For their principal chemical and physical properties, see *Elements.*

Aluminium	Copper	Molybdenum	Tantalum
Antimony	Didymium.	Nickel	Tellurium (considered by some to be a non-metal)
Arsenic (considered by some to be a non metal)	Erbium	Osmium (considered by some to be a non-metal)	Thallium
	Glucinum.		Thorium
	Gold.		Tin
Barium	Indium	Palladium	Titanium.
Bismuth	Iridium	Platinum	Tungsten
Cadmium.	Iron	Potassium	Uranium
Cæsium.	Lanthanum	Rhodium	Vanadium
Calcium.	Lead	Rubidium	Yttrium
Cerium	Lithium	Ruthenium	Zinc.
Chromium.	Magnesium.	Silver	Zirconium
Cobalt	Manganese.	Sodium	
Columbium	Mercury	Strontium	

Metals seldom occur native, being generally met with in combination with oxygen, or sulphur, &c Metals unite with one another, forming what are called alloys (which see) (See also *Elements, Table of*)

METALS, COLOURS OF The colours of metals as seen in the ordinary manner by reflected light may be considerably intensified, and in some cases entirely altered by repeated reflection Thus, after being reflected ten times from polished surfaces of the same metal the colours are as follows —

Copper, . . .	Scarlet.
Gold, ...	Red
Silver, ...	Puro Yellow.
Zinc, ...	Indigo Blue.
Iron, ...	Violet

When a film of metal is sufficiently thin to transmit light the colour transmitted is generally complementary to that which is reflected This, however, does not always hold good, for light passing through gold leaf is green. When, however, the gold is in a finer state of division, such as may be obtained by precipitation, the colour is purple, which is complementary to the usual yellow colour of gold (See *Colours of Bodies*)

METALS, OPTICAL PROPERTIES OF From an elaborate investigation published by G Quincke (*Pogg Ann*, vol. cxix, part 3), we condense the following results Plates of gold, silver, and platinum are employed, so thin as to be transparent, and these are examined in the same way as other transparent bodies When light falls upon a thick plate of metal it pene-

trates to a depth which is about as great as the length of an undulation, the so-called metallic lustre being produced by the conjoint action of the exteriorly and interiorly reflected or dispersed light. The velocity of light through metals is one of the subjects studied by the author, and he has obtained, in the course of this investigation, the remarkable result that light travels faster through gold and silver than through a vacuum. But Faraday has shown that silver and gold films occur in different modifications, and M. Quincke finds that gold and silver metallic plates, through which light passes with a greater velocity than through air, may become spontaneously altered by simple standing, so as to transmit light with less velocity than it is transmitted by air. In the case of platinum it was always found that the light passed through with less velocity than through air. The ordinary polished silver and gold possess the same character as that modification of these metals which transmits light with the greater velocity. Their refracting indices are therefore less than unity.

METALS, SPECTRA OF. See *Coloured Flames*.

METASTANNIC ACID. (See *Tin, Binoxide*.)

METEORIC IRON. Iron is a frequent constituent of meteorites, sometimes constituting upwards of 90 per cent. of them. The other constituents which have been detected in masses of meteoric iron, are nickel, cobalt, copper, manganese, chromium, tin, magnesium, arsenic, lithium, sulphur, carbon, and chlorine, the nickel being usually present in the largest quantity next to the iron.

METEORIC SPECTRA. Mr. Alexander Herschel has succeeded in observing the spectra of meteors; he finds them to vary much in appearance, some giving continuous spectra, others bright lines. Sodium is a frequent constituent, sometimes, indeed, almost the only one visible.

METEOR. (μετα, in the midst of; ἑώρα, suspension in the air; μετέωρος, that which is in mid-air.) A name originally given to any phenomenon taking place in the atmosphere, whether really aerial, optical, or otherwise. Its use is now beginning to be almost entirely limited to luminous meteors. (See *Meteors, Luminous*.)

METEOROLOGY. (μετεωρολογία.) The science which treats of atmospheric phenomena. The term originally included the study of all appearances in the heavens, whether atmospherical or astronomical; but it is now applied only to the science which treats of the phenomena of weather and climate.

Meteorology must doubtless have been studied in very early ages. In ancient times, men spent so large a portion of their time in the open air, and in pastoral or agricultural pursuits, that they must early have begun to pay attention to those signs which indicate change of weather. We find, accordingly, side by side with astronomical speculations, collections of weather portents, forming part of the very earliest works which have been handed down to our time. Such lore as this appears in the Works and Days of Hesiod, and in the Diosemeia of Aratus. Later, Aristotle collected the popular weather portents in his work on meteors. Theophrastus, Virgil, Cicero, Lucretius, and others have presented more or less fully the weather wisdom of the ancients.

The more exact and systematic inquiries of modern times may be said to have begun with the invention of the barometer by Torricelli in 1643, though the air-thermometer had been invented half-a-century before that date by Sanctorio of Padua. Fahrenheit's improvement in the thermometer in 1714, and the invention of the hygrometer (first used, though in a very imperfect form by Saussure) led to the further advance of the science, by placing at the disposal of men of science the means of measuring the heat and moisture of the earth's variable envelope.

The history of meteorological research records the interpretation of the trade winds by Hadley in 1735, Dalton's investigation of the aqueous phenomena of the air half a-century later, the work of Daniell in the beginning of the present century, and so to the labours of Humboldt, Dové, Kaemtz, Tyndall, and a host of eminent men in the present day.

The various branches of meteorological inquiry will be found dealt with under the heads *Atmosphere, Climate, Clouds, Wind, Rain*, &c.

METEORS, LUMINOUS. We propose to include under this head the consideration of all those objects, as shooting-stars, fireballs, asteroids, &c., which are now known to be visitants from the interplanetary spaces.

From the earliest ages men have recognised the fact that in the upper regions of air luminous objects resembling stars make their appearance, sweep athwart the heavens, and then vanish from view; that other objects, apparently larger, make their appearance in the same way, but seem during their progress through the air to undergo a process of disturbance (sometimes following contorted paths, and exhibiting a train of light and smoke, at others dividing into two or more separate masses, at others bursting with loud explosion into fragments); and, that other bodies (see *Asteroids*) actually reach the surface of the earth, their substance exhibiting

traces of the action of violent heat to which these bodies have been subjected during their progress through the air It has farther been long known that these objects pass through our atmosphere during the day-time also, though not then commonly visible by their light, but as suddenly appearing smoke clouds Finally, it has been long known that at times shooting stars appear in great showers

Without pretending to give a history of the progress of earlier research into the nature of these strange appearances, we shall now detail the observations which have been made in recent times, and show how they lead us to the true theory of these objects

The first observation which bears importantly on the views we are to form respecting meteors, is the discovery of the fact that on certain days of the year, shooting stars fall either in showers or in greater number than usual, a similar tendency is observed in the case of fire balls, though no absolute shower of these objects has ever been observed Aerolites, too, have been found to fall more frequently on some days of the year than on others

Now the occurrence of a phenomenon of this sort on particular days of the year is full of significance We cannot for a moment suppose that certain days in the year are more favourable than others for the occurrence of purely atmospheric phenomena, so that we are compelled to abandon the theory that shooting stars indicate (as some of the ancients supposed) the action of electric or other processes in the air Again we are forced to reject the theory that the moon is the source whence these objects reach our atmosphere for, were this the case, the month and not the year would measure their periodic recurrence So that we need not consider the elaborate researches by which such astronomers as Laplace and Olbers have exhibited the possibility that lunar volcanoes might project masses within the sphere of our earth's attraction In like manner we can at once dismiss the theory that these bodies have been projected from terrestrial volcanoes, since we know quite certainly that volcanic action is not restricted to particular days of the year, or in fact in any way associated with the earth's position in her orbit

We see at once that what we require is a theory which shall account for the fact that *when the earth comes to certain points of her orbit*, the phenomena of shooting-stars, &c are to be looked for Those points of her orbit are definite regions of the solar system, and we thus learn that certain regions of the solar system are to be regarded as in a sense *tenanted* by the objects, whatever they may be, which produce meteoric displays But we know quite certainly that no objects retain a fixed position in the solar system—except the sun himself An object placed at rest, where the earth is when meteoric displays are seen, would fall directly towards the sun These objects then are in motion, and as their motion must be rapid, and would therefore carry them away from the place where the earth encounters them, it follows (if we are to account for successive displays of star showers) that there must be a succession of these objects all passing athwart the earth's orbit

In other words, it has thus far been proved that the phenomena of shooting stars, fireballs, aerolites, &c, are due to the existence of bodies travelling in extensive orbits around the sun, and that the recurrence of periodic displays are due to the existence of streams or systems of bodies so travelling

But now a new fact was to point to a mode of learning what might be the orbits of these objects It was found that when shooting stars belonging to a periodic system make their appearance, their course is always directed from a fixed point on the celestial sphere It is obvious that this fact in itself suffices to prove that the meteors come from interplanetary space, for on no other hypothesis can we account for the fact that the meteoric paths have a vanishing point not referable to the earth but to the stars In a heavy shower of rain, falling continuously in any direction, we should find that the course of every drop tended from a vanishing point having a certain altitude and bearing, and so long as the direction of the wind remained unaltered, this vanishing point would remain unchanged in position But the vanishing point of a meteoric display rises and sets with the stars We learn farther from this fact, that the course of the meteors has not been much influenced by the earth's attraction For, clearly, if a flight of meteors were sailing slowly past the earth, and she, by her attraction, brought a number of them to her surface, the paths of these would show no traces of the original direction of the cluster's motion It is obvious, therefore, that the shooting stars must be travelling with planetary velocity, so that any velocity the earth can impart by her attraction is relatively insignificant

But then, the direction in which the meteors reach the earth being known, we have the means of determining the actual direction with which they were travelling through space, if only we can determine the velocity with which they traverse our atmosphere It is obvious that if we do not know what proportion their actual velocity bears to the velocity with which the earth is moving in her orbit, we cannot eliminate the effects of this last-mentioned velocity

so as to determine the outstanding velocity belonging to the motion of the meteors round the sun.

Here observation at first failed, direct solution of the problem, indeed, was not to be hoped for. Shooting stars and fireballs appear so suddenly, and move so swiftly, that the most experienced observer cannot hope to time them exactly, and nothing but the most exact timing by two experienced observers separated by a considerable distance, (many miles at the least), combined with a true record of the path of the shooting star, from its appearance to its disappearance, could give the means of determining the real velocity with which these objects move.

So far as the height of appearance and disappearance was concerned, there was less difficulty, and it would seem to have been satisfactorily established by the researches of the Padre Secchi at Rome, Professor Newton in America, and Professor Alexander Herschel in England, that shooting stars appear at an average height of about 72 miles, and disappear at an average height of about 53 miles. Fireballs also have been observed even more satisfactorily, so that in a few cases we have some means of forming an opinion of the velocity with which they move. Thus a remarkable meteor appeared on April 29, which was observed by two practised observers, Messrs Baxendell and Wood, at Liverpool and Weston-super-Mare respectively, and from a careful comparison of their observations, Professor Herschel was able to show that this object appeared at a height of 52 miles vertically over Lichfield, travelled in a southerly direction at the rate of about 20 miles per second, and disappeared when over Oxford at a height of 37 miles, having traversed a course of about 75 miles. But even in this instance doubt rests on the estimated velocity, and in the great majority of cases no reliance whatever can be placed on the calculations by which astronomers have sought to determine the velocity of meteoric motion by direct observation.

But it was of such extreme importance that in some way or other the nature of the orbital motions of these meteors should be determined, that astronomers set themselves to inquire whether other ways of resolving the problem might not be found.

We have spoken of periodic displays of shooting-stars. There are two of these shooting star periods which are so well marked that astronomers have given special attention to their peculiarities. One is that which produces the well-known star showers of August 9-10, called of old the Tears of St Laurence, the other is that to which we owe the remarkable displays of shooting stars occurring on or about November 13-14.

The November star-showers exhibit a well marked periodicity of splendour. Three times in a century we have for a year, or two, three, or sometimes even four years in succession, showers of unusual magnificence. The cycle, then, within which these maxima recur is about 33 years in length. Now, it was clear that this cycle must in some way be associated with the period of revolution of these November meteors. But at first astronomers could not believe that so long a cycle as 33 years can be the actual period of the November system, for with such a period it was easily calculable that the aphelion of their orbit must be beyond the orbit of the planet Uranus. There were other ways of accounting for the cycle of 33 years, without adopting so startling a theory as this. A peculiarity of the November showers had to be accounted for, however, which seemed to promise to throw new light on this question. The shower occurs later and later year by year, and after taking into account the effect of precession, it was found that there is a real advance of the node of the meteor system on the ecliptic. But astronomers know how to calculate the motion of the node of a body circling in a given orbit about the sun. It remained, then, to try different periods. Given the period of the system, the velocity with which the meteors cross the earth's orbit could be at once determined, then, (the radiant being known), the actual direction in which they cross that orbit, and so the actual position and shape of their own orbit could be determined. Professor Adams applied his great powers to calculate the nodal motion of the November system on a variety of assumptions as to its period, all the assumptions, however, being adopted so as to explain the 33 year period already mentioned. One orbital period after another failed, until the period of 33 years was alone left untried. There were difficulties in treating the orbit corresponding to this period, on account of its great eccentricity. However, Adams applied a method invented at the beginning of the present century by Gauss to the solution of this difficult problem. He found that, on the assumption of a period of 33¼ years, the motion of the node is fully accounted for by the attractions of the planets Uranus, Jupiter, and Saturn. Thus, no doubt remained that this period, so long (and with reason) rejected by astronomers on account of the enormous extent of the orbit it gives the meteors, is the true period of the meteor system.

But, in the meantime, a startling discovery had been made. Schiaparelli had been led to inquire whether the coincidence that the comet of 1862 crossed the earth's orbit precisely where we encounter the August meteors, is accidental or not. It is evident that the August meteors

might cross the earth's path at this particular point in a myriad different directions Only one would coincide with the comet's track Now, Schiaparelli found that, assuming only a considerable eccentricity in the path of the meteors, that path actually coincides with the path of the comet The nature of the correspondence will be seen from the two following tables, the former giving the best estimates of the comet's path, the latter giving the orbit of the August meteors on the assumption that the eccentricity has the same value as that of the comet's path -

	Large Comet of 1862, (Comet III 1862)	August Meteors, (Schiaparelli's Elements)
Longitude of perihelion, . .	344° 41′	343° 38′
Longitude of ascending node, .	137 27	138 16
Inclination, . . .	66 25	64 3
Perihelion distance, . . .	0 9626	0 9643
Period, ...	123 74	——
Motion, ...	Retrograde	Retrograde.

The agreement is far too striking to be accidental Every astronomer, in fact, who studied the evidence attentively came to the conclusion that there was some association (though what its nature might be was unknown) between the August meteors and the bright comet of 1862)

But it was felt that the evidence would be complete if, now that an exact orbit was found for the November meteors, a comet could be shown to be associated with them also By a strange accident, the proper comet had been detected by telescopists (it was far too small to be visible to the naked eye) only a few months before Adams completed his labours Peters and Schiaparelli independently discovered that Tempel's comet (Comet I 1866) had elements which may be regarded as absolutely identical with those of the November meteors The following tables show this —

	November Meteors	Tempel's Comet.
Perihelion distance, . .	0 9893	0 9765
Eccentricity, . .	0 9033	0 9054
Semi-axis major, . .	10 340	10 324
Inclination, . .	18° 3′	17° 18 1′
Longitude of descending node, .	51 28	51 26 1
Period, ...	33ʸ 25	33ʸ 176
Motion, . .	Retrograde.	Retrograde.

Considering that astronomers had determined the principal features of the orbit of the November meteors from the estimated position of the radiant point whence the shooting stars seemed to proceed on the night of November 13-14, 1866, the coincidence cannot but be regarded as simply complete

Now, what the nature of the association between comets and meteors may be, it would be at present idle to inquire We are still so completely in the dark as to the nature of comets, and further, we know so little as to the condition of meteors as they traverse interplanetary space, that it would be fruitless to endeavour to show how it happens that bodies which seem to be like the lightest vapours, should be followed by bodies which would appear to traverse space as discrete masses of considerable density

But apart from all speculations on these points there are some results which seem so clearly deducible from what has been learnt respecting meteors that we do not hesitate to present them as a legitimate sequel to the account above rendered

Knowing *now* that meteors travel in orbits as eccentric as the cometic orbits, we have every reason to regard the fact that the earth encounters no less than 56 meteor systems, (as Professor Herschel says , but Professor Heis says she encounters more than 100), as affording positive proof that the total number of these systems must be counted by millions on millions

Again, we know that though some of these systems consist of bodies like those forming the November system, that is, of bodies scarcely exceeding a few ounces in weight, yet the components of some meteoric systems are bodies of considerable mass.

Yet further, the existence of countless millions of these systems within the planetary scheme leads to the conclusion that in the sun's neighbourhood meteoric masses must be distributed in amazing profusion. For an eccentric meteor system is a sort of radial appendage of the solar system , and the existence of a series of radial appendages around the sun involves the necessity of a relative crowding of matter in his neighbourhood

It seems to follow then, most conclusively, that there must exist all round the sun such streams and crowding systems of meteors as could scarcely fail to be rendered visible under

favourable circumstances, illuminated as they would be by the splendour of the sun whose orb is relatively so near to them

There seems good reason for believing that in the zodiacal light we do actually see this congeries of meteoric systems, or at least its outlying parts, while the solar corona presents precisely such an appearance as we should expect that system of systems to present in the immediate neighbourhood of the great centre about which each system is revolving

If the zodiacal light and the solar corona be thus explained, (and we can see no escape from the conclusion that this is the true explanation), modern researches into the theory of luminous meteors may not unfairly be said to have thrown a most important light on the whole economy of the solar system

METONIC CYCLE See *Cycle*

METRE (*μέτρον*, measure) The French unit of length (See *Metric System*)

METRIC SYSTEM The system of weights and measures first adopted in France, but now gradually coming into use in other countries We propose to describe under this head the present English and French systems of weights and measures, and to exhibit the relations between the two Until the metric system or some modification has been adopted in England it is absolutely necessary that the student of science in this country should have the means of readily translating weights and measures from one system to the other

The first point to be considered is the actual basis of each system, the standard to which each is primarily referable

The fundamental unit of English measurement is the yard It is determined by reference to the length of a pendulum vibrating seconds of mean time in vacuum in the latitude of London, at the sea-level This length is to be divided into 3913929 parts, and the yard is to contain 3600000 such parts The yard is divided into 36 inches, so that the pendulum beating seconds in the latitude of London contains 39 13929 inches (Properly speaking the inch is more justly to be regarded as the unit of length than the yard)

The English units of capacity and weight are derived directly from the unit of length The *standard gallon* contains 277 274 cubic inches, and the pound avoirdupois is the tenth part of such a gallon of distilled water at the temperature of 62° Fahrenheit when the barometer stands at thirty inches, the water being weighed at the sea-level. The pound weight is divided into 7000 grains

The measurement of surface is too closely associated with that of length to need special notice But to the above units we may add the unit of land measurement, the *acre*, containing 4840 square yards

In the French system the fundamental unit is the *mètre*, which is determined by reference to the length of a meridional circle It is the ten millionth part of the quadrant of the meridian of Paris The length of a mètre in English inches is 39 3707898, or nearly a quarter of an inch more than the length of a pendulum vibrating seconds in the latitude of London

The French unit of surface is the *are* of 100 square metres

The unit of capacity is the *litre*, the 1000th part of a cubit mètre

The unit of weight is the *gramme*, the weight of the 10,000th part of a cubic mètre of water at its maximum density (The kilogramme, or the weight of a litre of such water, is, however, commonly employed as more convenient)

The value of these units does not depend, however, on the accuracy with which the various measurements have been made by means of which their value has been determined It has, indeed, been shown by Sir John Herschel that there is probably an error of about the 20th part of an inch (in defect) in the determination of the French mètre, while Professor Miller of Cambridge has shown that the weight of the standard kilogramme is less than that of a cubic litre of water at its maximum density, having been deduced before this maximum had been accurately determined

However important the determination of the true length of a meridional arc may be in itself, (see *Earth, Figure of the*, *Latitude, Degree of*, &c,) or whatever interest may attach to the inquiry into the true maximum density of water, the value of a system of national weights and measures is in no sense impaired by slight differences such as those referred to

The essential excellence of the metric system is derived from the mode of multiplication and subdivision of the units according to a uniform decimal notation.

The multiples of the different units are indicated by prefixing Greek names of numbers to the name of the unit, the subdivisions by prefixing Latin names of numbers These prefixes are therefore for decimal multiples, *déca-*, *hecto-* (or *hect-*), *kilo-*, and *myria-*, and for decimal subdivisions they are *déci-*, *centi-*, and *milli-*

Thus for linear measurement we have the *mètre*, its multiples, the *décamètre* (ten mètres), the *hectomètre* (one hundred mètres), the *kilomètre* (one thousand mètres), and the *myriamètre*

ten thousand mètres), and its sub-divisions, the *décimètre* (one tenth of a mètre), the *centimètre* one hundredth of a mètre), and the *millimètre* (one thousandth of a mètre) (The importance of distinguishing between *déca-* and *déci-* will be noticed)

In like manner for weights, we have the *gramme*, its multiples, the *décagramme* (ten grammes), the *hecto-gramme* (one hundred grammes), the *kilogramme* (one thousand grammes), and the *myriogramme* (ten thousand grammes), and its subdivisions, the *décigramme* (one tenth of a gramme), the *centigramme* (one hundredth of a gramme), and the *milligramme* (one thousandth of a gramme)

It will be seen that two advantages follow from this plan In the first place, the same prefixes are used in measures of length, surface, capacity, and weight, so that when known for one set of measures they are known for all And secondly, a decimal system of multiplication and division being used throughout, no processes resembling compound addition, subtraction, multiplication, and division, are required in dealing with these measures, but only the same simple processes which are employed for the addition, subtraction, multiplication, and division of abstract numbers

For the conversion of metric numbers into English measures we give the following tables, compiled by Mr. Warren De La Rue

I —LENGTH

	In English inches	In English feet	In English yards	In English miles
Millimètre,	0 03937	0 0032809	0 0010936	0 0000006
Centimetre,	0 39371	0 0328090	0 0109363	0 0000062
Decimetre,	3 93708	0 3280899	0 1093633	0 0000621
Metre,	39 37079	3 2808992	1 0936331	0 0006214
Décametre,	393 70790	32 8089920	10 9363310	0 0062138
Hectometre,	3937 07900	328 0899200	109 3633100	0 0621382
Kilometre,	39370 79000	3280 8992000	1093 6331000	0 6213824
Myriometre,	393707 90000	32808 9920000	10936 3310000	6 2138244

1 inch = 2 539954 centimetres | 1 yard = 0 91438348 metre
1 foot = 3 0479449 decimetres | 1 mile = 1 6093149 kilometre

II —SURFACE

	In English square yards	In English square poles = 30 25 square yards	In English square roods = 1210 square yards	In English acres = 4840 square yards
Centiare or square mètre,	1 1960333	0 0395383	0 000988457	0 0002471143
Are or 100 square mètres,	119 6033260	3 9538290	0 098845724	0 0247114310
Hectare or 10,000 "	11960 3326020	395 3828959	9 884572398	2 4711430996

1 square inch = 6 4513669 square centimètres | 1 square yard = 0 83609715 square mètre
1 square foot = 9 2899683 square decimetres | 1 acre = 0 404671021 hectare

III —CAPACITY

	In Cubic Inches	In Pints	In Gallons	In Bushels
Millilitre,	0 061027	0 001761	0 00022010	0 000027512
Centilitre,	0 610271	0 017608	0 00220097	0 000275121
Décilitre,	6 102705	0 176077	0 02200967	0 002751208
Litre,	61 027052	1 760773	0 22009668	0 027512085
Décalitre,	610 270515	17 607734	2 20096677	0 275120846
Hectolitre,	6102 705152	176 077341	22 00966768	2 751208459
Kilolitre,	61027 051519	1760 773414	220 09667675	27 512084594
Myriolitre,	610270 515194	17607 734140	2200 96676750	275 120845937

1 cubic inch = 16 3861759 cubic centimètres | 1 cubic foot = 28 3153119 cubic décimetres
1 gallon = 4 543457969 litres

IV —Weight

	In English Grains	In Troy Oz = 480 Grains	In Avd Lbs = 7000 Grains.	In Cwts = 112 Lbs
Milligramme,	0 015432	0 000032	0 0000022	0 00000002
Centigramme,	0 154323	0 000322	0 0000220	0 00000020
Décigramme,	1 543235	0 003215	0 0002205	0 00000197
Gramme,	15 432349	0 032151	0 0022046	0 00001968
Décagramme,	154 323488	0 321507	0 0220462	0 00019684
Hectogramme,	1543 234880	3 215073	0 2204621	0 00196841
Kilogramme,	15432 348800	32 150727	2 2046213	0 01968412
Myriogramme,	154323 488000	321 507267	22 0462126	0 19684118

1 grain = 0 064798950 grammes
1 lb Avoirdupois = 0 45359265 kilogramme
1 oz Troy = 31 103496 grammes
1 cwt = 50 80237689 kilogrammes

The following tables, taken from a paper by Mr Royston-Pigott, will also be found very useful for special purposes —

British Inches	Millimètres	Millimètres	British Inches
1	25 39954113	1	0 039370789
2	50 79908226	2	0 078741579
3	76 19862339	3	0 118112369
4	101 59816452	4	0 157483159
5	126 99770566	5	0 196853949
6	152 39724679	6	0 236224738
7	177 79678792	7	0 275595528
8	203 19633905	8	0 314966318
9	223 59587018	9	0 354337108
10	253 99541132	10	0 393707898
12 (foot)	304 79449358	20	0 787415796
20	507 99082226	40	1 574831592
30	761 98623396	50	1 96853949
36 (yard)	914 38348075	100	3 93707898
40	1015 98164528	1000 (mètre)	39 3707898
50	1269 97705566		
100	2539 95411326		

Grains.	Grammes	Grammes	Grains
7	453592	1	15 43234874
14	907185	2	30 86469748
21	1 360777	3	46 2970[illegible]
28	1 814370	4	61 72939[illegible]
35	2 267963	5	77 16174370
70	4 535926	10	154 32348740
140	9 071852	11	169 75583614
350	22 679632	20	308 6469748
700	45 359265	50	771 617437
7000 (one pound avoird)	453 592652	100	1543 234874
		1000 (kilogramme)	15432 34874

It will be noticed that the first column deals with decimal parts of one pound avoirdupois See *Essay on the Yard, the Pendulum, and the Mètre*, by Sir John Herschel, *Briot's Arithmetic*, translated by J. Spear, &c , a paper by Mr Spear in the Popular Science Review for October 1864; and another by Mr Royston-Pigott in the same magazine for July 1870

METROCHROME. (μετρον, a measure, and χρωμα, colour) An instrument devised by Sidney B. Kincaid for measuring colour He has employed it for the estimation of star colours It consists essentially of three parts—1, a lantern for the production of a constant light, 2, a contrivance for imparting to that light the necessary colour, and so arranged that the proper tinge being once produced, a record of it can be obtained, so as to enable it to be reproduced at any time, 3, an apparatus to throw that coloured light into the field of the telescope as an arti-

ficial star, which can thus be viewed side by side with the image of the real one The source of light is a very fine platinum wire, rendered incandescent by a current of electricity, transmitted through it from a Smee's battery of two cells The platinum wire is brought into the focus of a lens, so that the rays of light from the lantern issue parallel, and therefore come to a focus after passing through the object-glass of the telescope, at the same distance from it as those emitted by a star The chromographic part of the apparatus consists of a drum rotating about an axis The drum has in it six equidistant radial openings, the alternate three of them transmitting the normal light of the lantern, the other three constructed so as to admit flat-sided stoppered bottles, containing chemical solutions of different colours The outer edge of each of the last mentioned apertures is graduated into ten parts, and each of these can be wholly or partially closed by means of a radial shutter The other three apertures can be simultaneously closed wholly or partially by a triune radial shutter The edge of one of them is divided into ten parts, and as all are equally affected by the movement of the shutter, the reading applies to the three openings The drum is made to rotate so as to bring successively the different apertures in front of the lantern, and when the rotation is sufficiently rapid, the impression of colour produced on the retina of the eye will be that of a colour compounded of the colour of the solutions in the three alternate apertures diluted by the white light transmitted through the other three alternate apertures By a proper selection of the solutions, and adjustment of the magnitude of the several apertures by means of the shutters, it is possible to produce the exact colour of a particular star, and then the record of the solutions employed, and of the dimensions of the several apertures, will enable the exact reproduction of such colour at any future period for comparison with the then colour of the star in question The remaining part of the apparatus is a contrivance for throwing the beam of coloured light into the telescope, so as to produce, as already mentioned, the image of an artificial coloured star

MICROCOSMIC SALT See *Phosphorus*

MICROMETER, DOUBLE IMAGE See *Double Image Micrometer*

MICROMETER EYE-PIECE (μικρος, small, and μετρον, a measure) This consists of an eye-piece having a ruled glass micrometer, or a spider thread micrometer, in its focus The image of the object and the lines of the micrometer are thus distinctly seen at the same time, and measurements can be readily obtained The ruled glass is sometimes stationary, and sometimes connected with a screw and graduated milled head, so as to read off the measurements at the side The spider-thread micrometer consists of two spider threads fixed in the focus of the eye-piece, one of which is stationary, whilst the other is allowed to traverse the field, keeping parallel to the first This is also moved by means of a fine screw and graduated milled head Sometimes, instead of one moving wire, the frame carries two, crossing each other at an angle It is easier with this arrangement to get the accurate coincidence of an object with the point where the threads cross, than with the straight thread (See *Eye-piece Micrometer*, and *Parallel Line Position Micrometer*)

MICROSCOPE (μικρος, small, and σκοπεω, to view) An optical instrument by means of which magnified views of very minute objects can be obtained Microscopes are divided into simple and compound. In the former, the object itself is directly magnified by one or more convex lenses (See *Doublet*, *Triplet*) In a compound microscope, a highly magnified image of the object is first formed, and this image is then treated like the real object in a simple microscope, the eye-piece here acting as the magnifier (See *Compound Microscope*, *Dichroic Microscope*, *Reflecting Microscope*, *Binocular Microscope*, *Solar Microscope*, *Spectrum Microscope*, *Polarising Microscope*)

MICROSCOPE, BINOCULAR STEREOSCOPIC See *Binocular Stereoscopic Microscope*)

MICROSCOPIUM (The microscope) One of Lacaille's southern constellations.

MICROSPECTROSCOPE Synonymous with the *Spectrum Microscope*, which see.

MILKY WAY See *Galaxy*

MINERAL CHAMELEON See *Manganese*

MINERALS, HARDNESS OF. See *Hardness of Minerals*.

MINIMUM THERMOMETER A thermometer so constructed as to register the lowest temperature during a day, or any given interval of time The principle on which it is constructed is the reverse of that adopted in the maximum thermometer In *Rutherford's minimum thermometer*, the spirit of wine is used instead of mercury, and a steel index is placed in the tube, the thermometer being suspended horizontally As the temperature falls, the index is carried down by the spirit, but when the temperature rises, the spirit passes the index, and leaves it to indicate the lowest temperature reached during the day A magnet may be employed in setting the instrument, or else the bulb end must be raised

It must be noticed specially in employing this instrument, that the spirit of wine is apt to

collect, after evaporation, at the top of the tube It need hardly be said that, unless this end of the tube be free from spirit, the minimum registered will be too low.

MINIUM See *Lead, Oxides*

MINTAKA (Arabic) The star δ in the belt of the constellation Orion.

MIRA. (The wonderful star) The star o of the constellation Cetus A remarkable variable star (See *Stars, Variable*)

MIRACH (Arabic) A name which has been given both to the star β of the constellation Andromeda, and to the star ϵ of the constellation Bootes. Each star is also sometimes called Mizar

MIRAGE (French, from the root of *mirror*, L, *miror*, to wonder at) A phenomenon of unusual refraction It is produced by the sun shining on a sandy desert, and heating the sand and lower stratum of air It gives the appearance of lakes or inundations in the distance, the villages on elevations being apparently reflected in water It is probably due to total reflection from the boundary surfaces of two strata of air of unequal densities. (See *Refraction, Unusual*)

MIRFAK. (Arabic) The star α of the constellation Perseus.

MIRROR (*Miror*, to wonder at) A polished substance used for reflecting light For optical purposes they may be made of plane glass, glass coated behind with tin amalgam (looking-glass), glass coated in front with a highly reflecting silver or platinum film, or of speculum metal Mirrors are *plane, convex, concave*, and *parabolic*, which see.

MIRROR GALVANOMETER See *Galvanometer*.

MIRRORS, SILVERED See *Silvered Mirrors*

MIRZAM (Arabic) The star β of the constellation Canis Major.

MIST See *Fog*

MISTRAL A violent (but steady) north-westerly wind blowing from the south eastern parts of France across the Gulf of Lyons

MIZAR (Arabic) (See *Mirach*) Mizar is also a name given to the star ζ of the constellation Ursa Major

MOBILE EQUILIBRIUM OF TEMPERATURE See *Theory of Exchanges*.

MODULUS OF ELASTICITY See *Impact*, and *Elasticity*

MOIRÉE METALLIQUE See *Tin*

MOLECULAR POTENTIAL ENERGY When a ball is thrown up into the air it possesses, besides its actual motion or *vis viva* (otherwise called kinetic energy), a certain amount of other energy, called *potential energy* At any moment of its ascent it possesses the actual motion which is urging it upwards, *plus* the possible motion—the motion existing in possibility not in act—due to gravity, which will cause it to descend to the earth when it reaches the summit of its flight This is the potential energy of a mass In like manner, a man in a balloon, a hanging lamp, a pith ball suspended in the vicinity of a charged electrical conductor, two bodies whose chemical union is imminent, and a piece of iron suspended near a magnet, are each and all in a condition of potential energy, because there is an action possible to them which is not possible when they are removed from the several attracting forces which influence them In fact, whenever matter is under the influence of an attractive force, in a restrained position, so that it can be actuated by that force only when the restraining influence is removed, it is in a condition of potential energy Now, when we heat a substance, a part of the heat is consumed in the performance of mechanical work (see *Internal Work of a Mass of Matter*)—it has to overcome the cohesion of the particles before it can separate them Suppose we heat a bar of iron to redness, the particles are further apart than before heating (see *Expansion*), and heat has been converted into mechanical force in separating them They are in a condition of potential energy, and resemble a suspended weight This is *molecular potential energy* the potential energy of small masses As the heat which caused their separation passes off during the cooling of the mass, cohesion reasserts its power, and the particles approach each other, they resemble a ball falling to the earth, a pith-ball approaching an electrified conductor, a piece of iron a magnet, or a molecule of oxygen a molecule of phosphorus, save that they are actuated by the force of cohesion instead of by gravity, electricity, magnetism, or chemical affinity. An enormous force is exercised during this contraction, it would take more than a ton weight to stretch a bar of iron of a square inch in section to the same extent that a rise of temperature of 9° C effects, and the same force is exerted in the opposite direction during cooling A short bar of iron half an inch thick may easily be broken by the contraction of a larger bar which has been heated to redness and is suffered to cool Moreover, this contractile force has been applied for the purpose of bringing together the walls of buildings, which have ceased to be perpendicular from sinking of the soil or other causes. Thick rods of metal are passed through the opposite walls, and are fastened on the outside by means of a screw on the rod itself The nut is screwed up tight, and the rod then heated to redness, it lengthens, and the screw can be

tightened ; as the rods cool they shorten, and the walls are drawn slightly closer By repeating this many times a sensible effect may be produced, and the walls ultimately brought to parallelism The most notable application of this was made in the *Conservatoire des Arts et Metiers* in Paris, the walls of which were commencing to bend outwards, but were straitened by thus utilising the intensity of molecular forces On the same principle, the tires of wheels are put on while red hot, as are the iron hoops of tubs and barrels

In the case of substances which have been suddenly cooled, such as unannealed glass (see *Prince Rupert's Drops*), the molecules are in a condition of potential energy, and when they are released from the state of strain by rupture of continuity at one point, the potential energy becomes kinetic, and the kinetic energy becomes heat

Molecules may be in a condition of potential energy under the influence of the attractive force, called chemical affinity Instances of this are of perpetual occurrence in chemistry When a substance is decomposed by heat a certain amount of heat disappears, and is consumed in separating the molecules , when they rush together again to combine and form the original substance the same amount of heat is produced by the collision of the molecules as was consumed in separating them They are in the condition of the raised weight, then of the falling weight, then of the weight which has reached the earth and yielded up its kinetic energy, which becomes heat Suppose, for instance, we have lead in the finely divided state in which it is called lead pyrophorous , it is in a condition of molecular potential energy , a certain amount of heat has been consumed in bringing it to that condition, and when the molecules are brought into the presence of oxygen gas they combine with it The molecules of lead come into collision with the molecules of oxygen, and the heat consumed in separating them reappears When molecules are in a condition of potential energy under the influence of their own cohesion , that is, when, as in the first example given above, heat has expanded a body, and thus conferred potential energy upon its molecules, a certain amount of heat disappears in the performance of internal work, and when, on cooling, the molecules assume their original position, the amount of heat which was consumed in separating them reappears (See also *Specific Heat*, *Internal Work of a Mass of Matter*)

MOLECULE (Diminutive of L *moles*, a mass) The smallest quantity of a compound which can take part in a chemical reaction. Thus the molecule of water is $H_2O = 18$, and of ammonia, $H_3N = 17$

MOLYBDENITE See *Molybdenum*.

MOLYBDENUM A metal discovered by Hjelm in 1782 Symbol Mo Atomic weight, 96 It is scarcely known in the metallic state, but is said to be a silver-white, very hard, almost infusible metal, of specific gravity 8 6 Its most important compounds are —

Molybdic Oxide (MoO_2) A red brown powder, precipitated as a hydrate, and soluble in acids, forming molybdic salts

Molybdic Acid (MoO_3) This is a white, silky-looking crystalline powder, of specific gravity 3 49, fusible at a red heat, slightly soluble in cold water, forming a slightly acid solution By dialysis, Graham prepared a strong aqueous solution of molybdic acid, which, on evaporation to dryness, left the acid in a gum-like mass Molybdic acid unites with bases forming molydates Molybdic acid dissolves in ammonia The solution, when rapidly evaporated, deposits a crystalline powder, having the composition $(NH_4)_2O\ 2MoO_3$, when evaporated slowly in the air, large transparent prisms are deposited, having the composition $(NH_4)_4H_6Mo_5O_{20}$

Disulphide of Molybdenum (MoS_2) Occurs native as *Molybdenite* It is very soft, and crystallises in thin plates of a lead gray metallic lustre It is easily cut Specific gravity 4 4 This is the usual source of Molybdenum compounds

MOMENT OF INERTIA If a body be supposed to consist of a large number of heavy particles, and the mass of each be multiplied by the square of its perpendicular distance from a given line or axis, the sum of all the products is the *moment of inertia* of the body with respect to the axis The moment of inertia is a quantity that enters nearly every question in which the rotatory motion of a body is concerned , for example, when a body under the action of a number of forces is free to move only about a fixed axis, it is found that the angular acceleration about the axis is equal to the moment of the forces divided by the moment of inertia about the axis.

MOMENTUM The product of the mass of a moving body into its velocity It is a measure of the force accumulated in a moving body A ball of lead weighing 10 lbs, and moving with a velocity of 15 feet per second, would strike an obstacle with the same force as a ball 30 lbs in weight, and moving with a velocity of 5 feet per second The momentum depends on the mass and not on the weight, for a given mass of lead, moving with a given velocity, would strike the same blow in England as in India, although the acceleration of gravity, and, therefore, the weight, would not be the same in the two places. When a body in motion

imparts motion to another, as when a ball in motion strikes another at rest, the momentum lost by the first is exactly equal to that gained by the second When a system of bodies is in motion, the sum of the momenta of the parts of the system in any direction is equal to the momentum in that direction of the whole mass collected at the centre of gravity

MONALKALAMINES See *Amides*

MONATOMIC ALCOHOLS See *Alcohols, Series of*

MONAMIDES See *Amides*

MONAMINES See *Amides*

MONOCEROS. (The Unicorn) One of the northern constellations, formed by Hevelius It contains many objects of interest to the telescopist The triple star 11 Monocerotis has been described by Sir Wm Herschel as one of the finest objects in the heavens

MONOCHORD (μονος, sole, only, and χορδη, chord) A musical instrument of one string invented by Pythagoras It was used at an early period for the investigation of the laws of the vibration of strings Thus Ptolemy measured and proved all his intervals by it Although originally, as the name imports, it had only one string, the modern form of the instrument consists of a long box upon which two strings are stretched One string has one extremity fixed, and the other attached to a weight; the extremities of the other string are wound round screws fixed to the box The lengths of the vibrating parts of the strings may be increased or diminished by moveable bridges (See *Vibrations of Strings*)

MONOCHROMATIC LAMP (μονος, single, and χρωμα, colour) A lamp which emits rays of one refrangibility only Light of this kind is frequently required in optical experiments By introducing into a colourless spirit or gas flame a tuft of asbestos saturated with chloride of lithium, sodium, or thallium, monochromatic light of a red, yellow, or green colour may be obtained

MONOCHROMATIC LIGHT (μονος, single, and χρωμα, colour) Light of one refrangibility, and consequently of one colour

MONSOON (Arabic, *mausim*, a season) The name given to the trade winds and counter trade winds which blow in the Indian Ocean, the former from October to April, the latter from April to October In the summer months the Asiatic continent is heated more than the equatorial parts of the Indian Ocean, so that instead of air currents towards the equator there prevail air-currents from the equator, and precisely as the air-currents towards the equator are changed through the effects of the earth's rotation into north-easterly winds (see *Winds*), so the air-currents from the equator are changed through the same cause into south-westerly winds In a similar way monsoons prevail (though not quite in so marked a degree) over those parts of the Indian Ocean which lie to the north of Australia, north-westerly counter trade wind taking the place of the south easterly trade winds, during the summer months of the southern hemisphere, that is, from October to April

MONTH, ANOMALISTIC The mean period of the moon's revolution from perigee to perigee of her orbit It differs from the sidereal month because the perigee does not occupy a fixed position.

MONTH, NODICAL The period of the moon's passage from ascending to ascending, or from descending to descending node of her orbit It differs from the sidereal month because the position of the line of nodes is continually shifting, and from the anomalistic month because the line of nodes shifts at a different rate, and in a different manner, than the apsidal line

MONTH, SIDEREAL The period in which the moon passes through the twelve signs of the Zodiac It may be regarded as the period in which the moon, as seen from a fixed star would appear to describe a revolution around the earth Its length is not constant, sometimes exceeding, at others falling short, of its mean value 27 321661 days

MONTH, SYNODICAL. The common *lunar month*, or *lunation*, that is, the interval in which the moon goes through all her phases, as from new to new, or from full to full It is usually reckoned from new moon to new moon A synodical month exceeds a sidereal month because when the moon starting from any assigned position has completed a revolution around the earth, the latter body has advanced considerably in her orbit round the sun, and therefore the moon does not occupy the same position relatively to the sun that she had when she began the revolution. She has, in fact, still to advance through several degrees before regaining that position. The mean value of a synodical month is 29 530589 days

MOON The satellite of the earth, a globe 2165 miles in diameter, and travelling in a nearly circular orbit, at a distance of 238,800 miles from the centre of the earth The density of the moon is little more than half that of the earth, so that her mass is but about the 89th part of the earth's Gravity at her surface is such that a terrestrial pound if removed to the moon would weigh less than 3 oz The moon's apparent diameter varies from a minimum value of 29′ 21·9″, to a maximum of 33′ 31·1″.

The moon, in completing her circuit round the earth, presents varying phases One half of her surface is always illuminated by the sun, but as the moon rotates upon her axis the boundary between the dark and light hemispheres continually changes in position As the polar axis of the moon is nearly at right angles to the plane of her orbit, and that plane inclined at a small angle to the ecliptic, the boundary between the light and dark hemispheres appears to shift nearly as a half ring would which should have its ends at opposite extremities of a diameter of the moon's disc, and should rotate uniformly about that diameter as an axis The same hemisphere of the moon is, however, always turned towards us, the moon's rotation upon her axis being accomplished in the same time as her mean sidereal revolution This remarkable relation has been supposed to result from the action of the earth in long past ages in gradually diminishing the moon's rotation period (See *Libration*)

The moon presents a remarkable appearance under the telescope There are no traces either of oceans or of an atmospheric envelope The whole surface of the moon is diversified by plains, elevations, and depressions of different orders, which have been thus classified by Mr Webb (in whose admirable treatise, "Celestial Objects for Common Telescopes," the whole subject will be found very fully treated)

1 *Gray Plains*, called *seas*, but undoubtedly containing no water "They are usually darker than the elevated regions which bound them," says Webb, "but, with a strong general resemblance, each has frequently some peculiar characteristic of its own"

2 *Mountain Chains, Hills, and Ridges* These also are characterised by many varieties "Some are of vast continuous height and extent, some flattened into plateaus intersected by ravines, some rough with crowds of hillocks, some sharpened into detached and precipitous peaks" One of the most striking forms of elevation is that of narrow ridges, not much raised above the general level, but extending over enormous arcs of the moon's surface, and commonly connecting remarkable mountains or craters These seem to indicate the action of tremendous forces of upheaval, bursting open parts of the moon's crust, and acting more or less effectively according as the resistance experienced has been less or greater

3 The *Crater-Mountains* These are, as Mr Webb justly remarks, the characteristic peculiarities of the moon Although cratered mountains are not unknown on the earth, yet the crater is in all such instances far smaller than the cone, whereas on the moon the crater is relatively of enormous extent There are also few signs of the emission of lava-streams from lunar craters Within some craters signs of change have been suspected Mr Birt, for instance, who has paid much attention to the subject, recognises variations in the visibility of markings on the floor of the lunar crater Plato (See *Notices of the Royal Astronomical Society*, vols xxix and xxx) Recently it was suspected that the small lunar crater Linné, was in actual eruption, the eminent selenographer Schmidt, of Athens, stating that it was hidden under a cloud of light But it is now generally believed by astronomers that differences of illumination alone have been in question Mr Browning in particular has succeeded in tracing changes of appearance in Linné under varying illuminations, which seem fully capable of accounting for the peculiar appearances attributed by Schmidt to an eruption It must be remarked, however, that some of the signs of change remarked by Schroter, Gruithuisen, Webb, Birt, and others seem too marked to be regarded as merely apparent The eminent lunarians Beer and Madler, however, are not disposed to regard the moon's surface as liable to change of any sort

4 *Valleys* of various dimensions

5 *Clefts* (or *Rills*) These phenomena were first recognised by Schroter, but Gruithuisen, Lohrman, Beer and Madler, and Schmidt, have added largely to the number of known objects of this sort They are, perhaps, the most perplexing of all the lunar features Webb thus describes them —"These most singular furrows pass chiefly through levels, intersect craters (proving a more recent date), reappear beyond obstructing mountains, as though carried through by a tunnel, and commence and terminate with little reference to any conspicuous feature of the neighbourhood The idea of artificial formation is negatived by their magnitude, they have been more probably referred to cracks in a shrinking surface The observations of Kunowski confirmed by Madler, at Dorpat, seem in some instances to point to a less intelligible origin in rows of minute contiguous craters"

6 *Faults*, or "closed cracks, sometimes of considerable length, where the surface on one side is more elevated than on the other"

The elevation of the lunar mountains admits of being measured with considerable accuracy by observations made on their shadows Schroter has estimated the average height of the lunar mountains to be about 5 English miles, so that they bear a far more important ratio than terrestrial mountains to the globe on which they stand

From the instantaneous disappearance and reappearance of stars which are occulted by the moon, it may be concluded that if the moon have an atmosphere it must be one of very limited

extent (See *Lunar Theory*, *Month* (*Anomalistic*, *Sidereal*, and *Nodical*), *Precession*, *Nutation*, *Elements*, &c)

MOON CULMINATING STARS See *Longitude*

MOON, SPECTRUM OF THE This spectrum is essentially that of sunlight, modified as to its intensity in some portions by the colour of that portion of our satellite from which it is reflected (See *Sun, Spectrum of*)

MORIN'S APPARATUS A machine constructed by General Morin to illustrate the laws of falling bodies It consists of a cylinder capable of rotation about a vertical axis, and caused to revolve by the descent of a weight attached to a rope wound round a horizontal axle A toothed wheel is fixed at one end of the axle, the teeth working in an endless screw on the upper extremity of the axis of the cylinder Uniformity of rotation is secured by the action of a fly wheel, through another endless screw, on the toothed-wheel. The cylinder is surrounded with paper ruled with horizontal and vertical lines A cylindrical weight, fixed at the top of the machine when at rest by a catch, carries a pencil, the point of which is gently pressed by a spring against the surface of the paper. The weight is detached by pulling a cord, and is guided in its fall by two iron wires fixed in the vertical direction If the cylinder did not revolve, while the weight fell, the pencil would trace a vertical line upon the surface, while if the cylinder revolved, but the weight remained stationary, a horizontal line would be traced When, however, the cylinder turns and the weight falls, a curve is traced which is found to be a parabola The effect is the same as if the body were projected with a uniform horizontal velocity and allowed to fall under the action of gravity. The horizontal velocity of the cylinder for each unit of time is known, and it is found experimentally that the falling weight, at the end of a certain time, is at a point situated on the vertical line drawn from the point at which it would have arrived if it had moved horizontally only, and at distances from that point which increase as the square of the time, or as the numbers, 1, 4, 9, 16, &c, thus confirming the theory of falling bodies and coinciding exactly with the results obtained with Attwood's machine (See *Attwood's Machine*) The resistance of the air is neglected, the form of the weight and duration of the fall being such as to make this resistance inappreciable

The ratio of the velocity of the falling body at any point to the horizontal velocity of the cylinder is determined by drawing a tangent to the curve at that point, and producing it to meet the line representing the horizontal velocity, and dividing the perpendicular distance of the point from the horizontal line by the length of the line intersected between the tangent and the perpendicular (See *Falling Bodies*, *Laws of Motion*)

MORPHINE An organic alkaloid contained in opium, and constituting the most important of the numerous bases occurring in it In the pure state it crystallises in colourless transparent trimetric prisms, very slightly soluble in cold water, alcohol, and ether Its composition is $C_{17}H_{19}NO_3$ It has a bitter taste, and is a powerful narcotic much used in medicine It neutralises acids and forms a well crystallised series of salts

MOSAIC GOLD See *Tin, Sulphide*

MOVING FORCE A term applied to a pressure producing motion in a mass when it is measured by the additional momentum imparted to the mass in a unit of time If by acting for a second of time a force increase the velocity of a body from 12 feet to 20 feet per second the *moving force* is the mass of the body multiplied by 8 feet, or the increase of velocity per second The moving force bears the same relation to the momentum as the acceleration does to the velocity, for it is the increase of momentum in a second.

MULTIPLE STARS See *Stars, Double*, &c

MULTIPLIER, or ASTATIC GALVANOMETER, as it is very frequently called, is an instrument for detecting the existence and measuring the strength of an electric current Its construction and mode of action are as follows The lower needle of a very nearly astatic combination (which consists of two equal magnetised needles suspended horizontally one above the other with their like poles in opposite directions) is surrounded by a coil of wire within which it can turn freely round a vertical axis, the upper needle, of course, turning with it The latter moves over a circular card which is placed above the coil of wire and on which the degrees of the circle are marked The extremities of the coil of wire are brought to binding screws or cups of mercury for convenience of making connection with any wire or other body to be tested, and the whole instrument, except the screws or cups, is covered with a glass shade to protect it from currents of air To use the instrument it is placed so that the needles are perpendicular to the axis of the coil, or, in other words, in a plane parallel to the plane of the winding of the coil, and the wires from the supposed source of electricity are attached to the binding screws or mercury cups If there be any current passing the needles will tend to turn in a direction perpendicular to the line in which the current is passing, the side of the coil to which the poles turn depending on the direction in which the current is flowing This instrument can be made

very delicate, indeed, by increasing the number of turns of the coil, or by making the needles very nearly equal, and therefore the system very nearly astatic The more nearly equal they are the less is the directive force of the earth upon the system, and it is this that acts against the current which tends to set the needles at right angles to itself It will readily be understood that the action of all the parts of the coil upon the needle in its interior is in the same direction, that is, all the parts conspire to turn the poles the same way, and that the action of the upper portion of the coil on the needle above it also has the same tendency, the action of the lower part of the coil on the upper needle is of the opposite kind and tends to turn the system round in the other direction, but as it is much more distant it produces comparatively little effect

Galvanometers or multipliers similar to that described above, made with but a few turns of moderately thick copper wire, are constructed and known under the name *thermomultiplier*, and are used in experimenting on currents produced by heat They are made in this way because the electromotive force of thermo-currents is very small, and any resistence such as that of a long thin wire would so diminish the current as to make it insensible

MULTIPLYING GLASSES An amusing toy, consisting of a plano convex glass, having on the convex surface various flat faces, each of which being at a different angle from the plane surface of the glass, forms a separate prism, having a different refracting angle to that of its fellows When a luminous object, such as a candle is viewed through these, as many separate images of the object are seen as there are faces to the glass, and these are coloured by dispersion more or less as they approach the margin

MUNDIC See *Iron Sulphides*

MUPHRID (Arabic) The star η of the constellation Bootes

MURAL CIRCLE An instrument for determining the zenith distances of stars, and thence their north polar distance and its complements their declination It consists of a circle bearing a telescope, which revolves in the plane of the meridian, the whole being attached to a stone wall or pier of solid masonry

MUREXID A brilliant red and purple colouring matter, obtained, among other methods, by the action of ammonia on alloxantin, one of the products of the oxidation of uric acid It forms brilliant four sided prisms, which are of a rich metallic green colour by reflected light, and garnet coloured by transmitted light, and of which the formula is $C_8H_4N_6O_6$ It dissolves in water, forming a rich purple coloured solution, which dyes silk, wool, cotton, and leather, with very fresh and brilliant colours

MURIATIC ACID (*Muria*, sea salt) See *Hydrochloric Acid*

MUSCA (The fly or bee) A southern constellation formed by Bayer There is a small group of stars now restored to the constellation Aries to which the same name was given

MUSCULAR POWER The muscles of an animal are machines doing work As the work done by a steam engine is due to the force liberated during the combination of the fuel with the oxygen of the air, so the work of the muscles is derived from the oxidation of the food, which is indeed the fuel of the animal body from which both its work and heat are obtained (See *Food, Functions of*) The physiological processes of digestion, absorption, &c, convert the whole of the food, except the portion excreted *per anum*, into blood From the blood the muscles, as well as the other organs of the body, are nourished Like the rest of the body, the muscles undergo constant disintegration and require constant renewal The muscular tissue is substantially identical with albumin in composition, and the final result of its disintegration is, that it is oxidised, and a number of more or less simple compounds formed from it Of these carbonic acid, and, to some extent, water, are excreted through the lungs and skin, while the remainder, of which the most important are urea, uric and hippuric acids, and creatinin, pass away in the urine Other products of the metamorphosis, notably lactic acid and creatin, undergo further change within the body

The immediate origin of muscular power has been the subject of much study within the last ten years It was long believed, chiefly on the authority of Liebig, that this power was derived exclusively from the oxidation of the muscular tissue itself But it has been conclusively proved that this is not the case About 15 per cent of the weight of dry muscle consists of nitrogen, and as the whole of the nitrogen of the disintegrated muscle is known to be excreted in the urine, it is obvious that, by ascertaining the quantity of nitrogen in the urine excreted during a certain period, we can calculate the *maximum* quantity that can have been disintegrated during that time Now, in a celebrated experiment (*Phil Mag*, June 1866), Fick and Wislicenus did a definite amount of work (ascended the Faulhorn) on a non-nitrogenous diet, and, ascertaining from the nitrogen excreted the utmost quantity of muscle that could have been oxidised, they found that it was not sufficient to account for more than one third of the work done Subse

quent experiments by Frankland (see *Food*) have shown that the proportion of the work which could have been derived from muscular oxidation was even less than this

It is now believed that all oxidation, whether of tissue or non-organised liquid, which takes place within the muscle, may give rise to muscular contraction, and so to work The precise seat of the oxidation is still doubtful, though there are strong grounds for thinking that it takes place within the walls of the capillary vessels The force is probably set free as heat (Haidenhain), and is transformed, perhaps by the agency of the nervous system, into work in the substance of the tissue

The amount of force generated in the human body in twenty four hours varies, of course, extremely If the body remain unchanged in weight, the force generated may readily be calculated from the calorific value of the day's food (See *Food*) The force-value of a bare subsistence diet for one day is about 700,000 metre kilogrammes, but with the higher diet required for hard work, it is twice or even three times as much as this The average daily work of a hard-working labourer is about 108,000 metre kilogrammes (350 foot tons) The *internal* work of the heart, lungs, &c, is probably about the same The remainder of the force is directly evolved as heat (See *Animal Heat*)

MUSIC (*μουσική*, from Μοῦσαι and *τέχνη*, any art over which the muses presided) In the modern sense of the term, music treats of the combination of sounds in a manner agreeable to the ear For that part of the theory of music which treats of sounds produced in succession with musical notation, pitch, duration, and rhythm, see *Melody* For the relation of sounds produced simultaneously with the notation of musical chords, see *Harmony*, and for the names of musical intervals, and the relation between the theories of music and sound, see *Musical Interval*

MUSICAL INTERVAL

Definition Interval is a term in music used to designate the mutual relationship of sounds which differ in pitch, or are differently represented on the staff Thus since the two sounds *c-d* differ in pitch, the relation between them is an interval, and the sounds *b♯-c* also form an interval, because, although they are practically of the same pitch, they occupy different positions on the staff Relationship of the latter kind, as they only exhibit a difference on paper, are sometimes called *paper intervals*

Naming of Intervals The language of music supplies a name for every possible interval These names are always twofold, one being primary and the other secondary The primary name is a numerical one, determined by the number of places or degrees (lines or spaces) of the staff embraced by the two sounds forming the interval Two sounds standing upon the same degree of the staff form the interval of a *prime*, *e g*, or If the two sounds occupy the same degree, and are also of the same pitch, they are said to be in *unison*, or to form an unison or *pure prime*, *e g*, That the unison does not therefore constitute an interval, will be gathered from the above definition

Two sounds embracing *two* places on the staff, *e g*, or form the interval of a *second*, *three* places or a *third*, *four* places or a *fourth*, and so on

The musical staff, while it admirably adapts itself to the representation of the musical tonal system generally, does not coincide quite so closely as some persons wish with the simple diatonic series, its successive degrees being all equidistant, while those of the scale vary, being at one time a tone, at another a semitone Moreover, the tonal distance between two sounds occupying different positions of the staff may be increased or diminished simply by the use of "accidentals," without changing the positions of the notes Hence it is clear that some more specific designation than that given by the numerical name is required in order to determine the extent of an interval This is supplied by the *secondary names*, which are four in number, viz, *major*, *minor*, *superfluous* or *augmented*, and *diminished* or *imperfect*

The first two are used to distinguish the two different sizes of intervals which are found under each numerical name (except the prime), in the diatonic series (major) Thus the second is at one time a *semitone*, at another a *tone*, the former are called *minor seconds*, the latter *major* Similarly the thirds are sometimes a *tone and a half* apart, at others *two tones* It is the same with the *fourths*, *fifths*, *sixths*, and *sevenths* There are two sorts of each, differing by a semitone, the smaller being called *minor*, the larger *major*

Intervals that are one semitone less than the minor interval of the same numerical name are said to be *diminished* or *imperfect*, thus *c♯—e♭* is a *diminished third*, being one semitone less than the minor third *c—e♭* Intervals that are one semitone larger than the major intervals of the same numerical name, are called *superfluous* or *augmented* Thus *c-g* being a *major fifth*, *c—g♯* is a *superfluous fifth*.

Superfluous and diminished intervals may occur under each numerical name except the prime, of which there is no diminished species, the intervals *c*—*c*♯ and *c*—*c*♭ being both termed *superfluous primes*.

Intervals that are more than one semitone larger than the major, or smaller than the minor, are termed respectively *doubly superfluous* and *doubly diminished*, *e.g.*, *c*×—*e*♭ is a *doubly diminished third*, and *c*♭—*g*♯ is a *doubly superfluous fifth*.

The above simple method of distinguishing intervals is not the one usually followed in the case of the *fourth* and *fifth*. Thus the fourth, *f*-*b*, consisting of *three tones*, which, according to the above method, is called major, is by some writers called *superfluous*, and by others *pluperfect* or *tritone*, the smaller species, *e.g.*, *c*-*f* (two-and-a-half tones) being called *perfect* by some, and by others, oddly enough, the *major fourth*.

Similarly with the fifths, the fifth *b*-*f*—containing two tones and two semitones—and called by the above method the *minor* fifth, is more frequently known as the *imperfect* or *diminished fifth*, the other species of diatonic fifth, *e.g.*, *c*-*g*—containing three tones and one semitone—being called the *perfect* fifth.

These various designations of the diatonic fourths and fifths have arisen from an endeavour to express by its name something more than the mere *size* of these intervals, as, for example, their harmonic character. The larger species of fifth *c g*, and the smaller species of fourth *c f*, are known, according to an old and nearly obsolete classification of intervals into concords and discords, as two of the *perfect* concords. The term perfect being given to them, the other secondary terms were rendered necessary in order to distinguish the remaining species of the same intervals in the diatonic series. It will be shown, however, further on, that these so called perfect fifths and fourths are not in practice made absolutely perfect, so that the application of the term, and consequently of the others which it renders necessary, cannot be maintained on the score of correctness, and as they serve greatly to perplex the learner, by throwing an air of mystery and profundity about what is after all only a very simple and non-essential technical detail, it would be well if they were abolished. All that is really required in a system of names is that it shall enable us to distinguish one interval from another. The terms major and minor, as we have used them, together with the other terms superfluous and diminished, enable us to do this, and as they apply with equal appropriateness to intervals of every degree, they supply a series of secondary names that is at once uniform and easily understood.

In naming an interval the rule is to name the lower sound first, and to reckon upwards. If the opposite plan is adopted, it is customary to add the term *under* or *downwards*, *e.g.*, *a* is said to be the *under third* from *c*, or the third from *c downwards*, the third from *c* being ordinarily understood to signify the note *e*.

Inversion. When the lower sound of an interval is raised, or its upper sound is lowered to the extent of an octave, the interval is said to be *inverted*, and the resulting interval is called the *inversion* of the original one.

By inversion,	primes	become	octaves
,,	seconds	,,	sevenths
,,	thirds	,,	sixths.
,,	fourths	,,	fifths
Moreover, by inversion,	major intervals	become	minor.
,,	minor	,,	major
,,	superfluous	,,	diminished
,,	diminished	,,	superfluous

Equivocal Intervals. A comparison of the tonal extent of different intervals shows that one and the same tonal distance may occur under two or more names. All such intervals are said to be equivocal. Thus the tonal distance of one semitone at one time appears as a *superfluous prime* *c*—*c*♯, at another as a *minor second c*—*d*♭. This equivocalness of intervals arises from the peculiar character of musical notation. It is by no means, however, a defect of that notation, for by it the scale to which an interval belongs is more easily determined, and by the ready means it affords in harmony of making transitions from one scale to another it is the source of many very pleasing harmonic effects, which probably might not have been discovered but for the existence of this equivocalness.

The particular instance quoted above, viz., c—c♯ and c—*d*♭, has given rise to the introduction of two technical terms into the language of intervals which require notice. The superfluous prime c—c♯, inasmuch as it cannot be represented without the use of a *chromatic sign*, is called the *chromatic semitone*, whereas the minor second *c*—*d*♭, as it occurs in some diatonic series (*e.g.*, in scales of D♭, E♭, A♭, &c.), is called the *diatonic semitone*.

Intervals mathematically considered. In the foregoing treatment of our subject the semitone

is considered the smallest musical interval, the octave being divided into twelve such intervals, and the major scale series consisting of seven sounds succeeding each other by the well known order of

Tone, Tone, Semitone, Tone, Tone, Tone, Semitone,

the tones being in each case exactly double the size of the semitones

This is in fact a correct description of the system of sounds in use amongst practical musicians, and for practical purposes simply we might stop here But when the scientific basis of the scale is examined, it is found that this relation of the intervals does not exactly coincide with the natural relation

All sounds are produced by the vibrations of bodies, and as by varying the rate of vibration, or, which is the same thing, the length of the vibrating body, sounds are altered in pitch, it will be seen at a glance that the figures expressing the rate of vibration, or the length of the sound producing body, afford a convenient mode of expressing the relation of sounds more exact and intelligible than the ordinary and somewhat vague notation employed in music

It is found from the monochord (see *Monochord*), that whatever sound is produced when the whole string is made to vibrate, the *octave* of that sound is produced when *half* the length of the string only is made to vibrate Hence a note is said to be related to its octave in the ratio $1 : \frac{1}{2}$

Again, if *two thirds* of the string be made to vibrate the fifth, the major—or so-called perfect fifth—is produced So that a key note is related to its fifth by the ratio $1 : \frac{2}{3}$

In the same way the fourth—the minor or so called perfect fourth—is found to be produced by *three fourths* of the string A key-note is to its fourth sound therefore as $1 : \frac{3}{4}$

Still further, the *major third* is found to be produced by four fifths of the string, hence its relationship to the key note is represented by the ratio $\frac{4}{5} : 1$

By combining the above ratios, the lengths of string required to produce the remaining sounds of the scale may be obtained Thus the sixth being a major third above the fourth, is found by the proportion as $1 : \frac{4}{5} :: \frac{3}{4} = \frac{12}{20} = \frac{3}{5}$ = the sixth major

The seventh being a major third above the fifth, is found by similarly combining the ratios $\frac{2}{3}$ and $\frac{4}{5} = \frac{8}{15}$

The *second* being a minor (perfect) fourth below the fifth, may be found by combining the ratios $\frac{3}{4} : 1 :: \frac{2}{3} = \frac{8}{9}$

In this way a fractional expression is obtained for all the sounds of the scale, viz —

Do	Re	Mi	Fa	Sol	La	Si	Do
1	$\frac{8}{9}$	$\frac{4}{5}$	$\frac{3}{4}$	$\frac{2}{3}$	$\frac{3}{5}$	$\frac{8}{15}$	$\frac{1}{2}$

The fractions represent not only the proportionate lengths of string required to produce the various sounds, but also the relative speed of the vibrations Thus for the fifth of the scale the three vibrations should take place in the time of two of those of the key-note For the fourth, four vibrations should take place in the time of three of the key note, and so on If we call the note produced by 512 vibrations per second C, the numbers of vibrations of the notes of the scale commencing with C, will be as follows —

C	D	E	F	G	A	B	C′
512	576	640	680	768	856	960	1024

These numbers have the ratios indicated above If it be asked what notes of the scale will chord most completely when sounded simultaneously, we have but to select those represented by the simplest ratio, as, for example, 1st C and C′ or Do and Do, 2nd C and G, or Do and Sol, 3d C and F or Do and Fa, and so on

Let us now see how the system of scale used in the musical art adapts itself to the natural scale First let us compare with it the series of equal semitones by reducing the above fractions to whole numbers having the same ratios, and placing them side by side with similar numbers corresponding to the series of mean semitones This may be done by representing the length of string which will produce the first by 360, then the other lengths will be—

Do	Re	Mi	Fa	Sol	La	Si	Do
360	320	288	270	240	216	192	180

The interval 360–180 may be divided into 12 equal parts such that the ratio of any two is constant thus —Let x be the fraction which must multiply each number to give that of the semitone above When the operation is repeated 12 times, the 360 is reduced to 180, therefore $360 \times x^{12} = 180$ From this we obtain $x = 943875$, $360 \times 9438 = 339\ 795$, this number multiplied by 9438 gives 320 724, and so on. The table of mean semitones is therefore as follows —

Mean Semitones	Lengths of String for the Mean Semitones	Lengths of String for the Natural Notes
Key-note	360 000	360 = Key note
1st Semitone	339 795	
2nd "	320 724	320 = Second
3d "	302 723	
4th "	285 732	288 = Third
5th "	269 695	270 = Fourth
6th "	254 558	
7th "	240 771	240 = Fifth
8th "	226 786	
9th "	214 057	216 = Sixth
10th "	202 043	
11th "	190 703	192 = Seventh
12th or Octave.	180 000	180 = Octave

By this it appears the intermediate sounds of the natural scale are produced by strings a trifle *shorter* than those which produce the nearest approximating sounds on the series of mean semitones, and that consequently the latter are a trifle more or less *lower* in pitch.

These differences appear still more obvious when the intervals of the natural scale are expressed in mean semitones reckoned from the key note to each. Thus—

	Intervals in Mean Semitone	Consecutive Intervals
Key-note from key note,	0 0000	
Second, "	2 0391	= 2 0391
Third, "	3 8631	= 1 8240
Fourth, "	4 9804	= 1 1173
Fifth, "	7 0195	= 2 0391.
Sixth, "	8 8436	= 1 8241
Seventh, "	10 8827	= 2 0391
Eighth, "	12 0000	= 1 1173

This shows that the gradations of the natural scale, measured in mean semitones, are of three different sizes, viz.—

2 0391, 1 8340, and 1·1173

These are called respectively the *major tone*, the *minor tone* and the *limma*. The difference between the major and minor tone is ·2151 of a mean semitone, and is called a *comma*. The order of the intervals of the natural scale is, therefore, as follows when t = major tone, $t_{,}$ the minor tone, and 0 the *limma* —

C		D		E		F		G		A		B		C
	t		$t_{,}$		0		t		$t_{,}$		t		0	

Suppose an instrument like the pianoforte, harp, or organ were provided with strings tuned for one such scale, say the scale of C. Then let it be required to play over the scale upon any one of its sounds, say upon its dominant G. We should find that the first interval *g a* is a t, whereas it should be a $t_{,}$. For the A of the key of G, therefore, a string would be required *one comma* higher than the A of the key of C. By pursuing this experiment it would be found that in order to supply the musician with a similarly perfect scale upon every sound he employs, an almost infinite number of strings would be required. This would render the mechanism of keyed instruments so complex, that if it were possible to arrive at absolute perfection in their construction and tuning, it would be next to impossible to play upon them. Again the human ear is not capable of distinguishing such infinitesimal differences in the pitch of sounds as those existing between the sounds of the natural scale and those of the more artificial one obtained from the series of mean semitones. Hence it is that practical musicians content themselves with the latter simple division of the octave on each sound of which an equal scale may be

based For though none of these scales are absolutely perfect, mathematically considered, the imperfections are too slight either to affect the melody of their intervals or the agreeableness of their harmonic combinations

MUSICAL SCALE See *Gamut*

MUSTARD, OIL OF See *Allyl Alcohol.*

N

NADIR. (Arabic) The point of the celestial sphere vertically beneath the observer

NAPHTHA (Persian, Arabic, *Nafth, Nafatha*, to boil) This word is applied to many liquids somewhat similar in physical properties, but differing chemically It was originally used to designate inflammable liquids issuing from the earth in certain countries, but it has since been allowed to include most of the lighter and more volatile inflammable liquids obtained by destructive distillation or from mineral oils. *Coal naphtha* consists in a great measure of commercial benzol and its homologues *Mineral naphtha* or petroleum oil is a complicated mixture of hydrocarbons, consisting almost entirely of the series of alcoholic hydrides *Wood naphtha* is a name sometimes given to impure methylic alcohol

NAPHTHALINE An organic substance obtained as a by-product in the manufacture of coal gas and the distillation of naphtha It is in the form of brilliant white crystalline scales, having a strong odour, resembling that of coal-gas, it is insoluble in water, but readily so in alcohol, ether, and most oils Composition $C_{10}H_8$ Specific gravity 1 153 when solid, 0 9778 when melted It readily sublimes and condenses in rhombic plates, it melts at 175° F, and boils at 424° F, although it volatilises slowly at the ordinary temperature Naphthaline is a substance which has attracted the attention of chemists for many years, as it is obtained in enormous quantities, and is for the most part thrown away Recently, attempts have been made to utilise it in the manufacture of colouring matters, and some of its compounds and derivatives appear likely to be of commercial importance in this respect Its derivatives and products of decomposition are exceedingly numerous and complicated, and they have been the subject of examination by many eminent chemists A mere list of the names of these substances would fill several pages

NAPHTHYLAMINE An organic base prepared from naphthaline It consists of fine yellowish white crystalline needles, and has a most disgusting odour Composition $C_{10}H_9N$ It forms well defined crystalline salts, with acids, and some of its compounds and products of decomposition are likely to be of great commercial value as colouring matter By acting on its hydrochlorate with nitrite and hydrate of potassium, a compound is produced which has been called *azodinaphthyldiamine*, which crystallises in splendid needles, having a bright green metallic reflection It melts to a blood-red liquid, and colours boiling water yellow Acids colour the solutions deep violet, forming salts which crystallise with very brilliant colours This base and its compounds, or derivatives, are met with in commerce under various names as colouring matters

NARCOTINE An alkaloid contained in opium to the extent of 6 or 8 per cent, it crystallises in colourless transparent prisms, insoluble in cold water, and only slightly so in hot, it is dissolved by alcohol and ether, although not freely Formula $C_{22}H_{23}NO_7$ It is a strong narcotic, although not so powerful as morphia Narcotine was the subject of some elaborate investigations by Dr Matthiessen, who made some important discoveries respecting its constitution

NATH (Arabic) The star β of the constellation Taurus

NAUTICAL ALMANAC See *Ephemeris*

NAUTICAL ASTRONOMY This term has been used to describe those parts of astronomy which bear in an especial manner on navigation, as the rules for determining longitude and latitude, and the like

NEBULÆ (Cloudlets) The name given by astronomers to those celestial objects which present a cloudy appearance There is some difference of opinion as to the exact use of the term, some astronomers limiting the name nebula to those celestial objects which cannot be or have not been resolved into discrete stars, while others include under the name all objects which, under any telescopic power, whether great or small, present a nebulous aspect According to this latter usage, all star clusters not resolvable (even in part) by the naked eye, would be classed as nebulæ As the question of the real resolvability of a group is not easily determinable, it is perhaps better that the word nebula should be kept as a convenient general term, applicable according to the latter of the above usages

The ancients recognised only five nebulous patches on the heavens. It was not until after

the invention of the telescope that astronomers began to notice the existence of many objects of this class in the sidereal depths, and, indeed, even then, many years elapsed before the real importance of the search for nebulæ was recognised. When Messier began to form the list of 103 nebulæ with which his name is associated, more southern than northern nebulæ were known, the labours of Lacaille having resulted in the discovery of several of these objects in the southern heavens. But even Messier's list must be regarded as utterly meagre when brought into comparison with the series of discoveries effected by Sir William Herschel. He sent in list after list of nebulæ to the Royal Society, the objects in each list being counted by hundreds. So that at the close of his labours in this department of astronomy about 2500 nebulæ had been added to the catalogue of known objects. His son, Sir John Herschel, proved a worthy successor in these arduous labours. After undertaking a complete revision of his father's observations, during the course of which he discovered 500 new nebulæ, he proceeded to the South Cape and commenced the survey of the southern heavens. During this survey he discovered about 1700 southern nebulæ, and reobserved many others. Besides the nebulæ discovered by these two eminent astronomers, a few hundreds have been detected by other observers. The noble catalogue formed by Sir John Herschel includes nearly all that have been detected, the few which remain uncatalogued bringing up the total perhaps to 5600 or 5700 objects of this class. So that if all the discovered nebulæ could be seen at once, they would be spread over the heavens about as richly as the stars visible to the naked eye.

Classification of the Nebulæ.—Sir John Herschel thus presents his father's classification of the nebulæ:—

1st. Clusters of stars in which the stars are clearly distinguishable, these clusters being again divided into globular and irregular clusters.

2d. Resolvable nebulæ, or such as excite a suspicion that they consist of stars, and which any increase of the optical power of the telescope employed may be expected to resolve into distinct stars.

3d. Nebulæ, properly so called, in which there is no appearance whatever of stars, which again have been subdivided into subordinate classes, according to their brightness and size.

4th. Planetary nebulæ.

5th. Stellar nebulæ; and

6th. Nebulous stars.

Distribution of the Nebulæ.—Sir William Herschel noticed, during the progress of his survey, that the nebulæ are not distributed at random over the heavens, but exhibit a "marked preference for a certain district, extending over the northern pole of the Galactic circle, and occupying the constellations Leo, Leo Minor, the body, tail, and hind legs of Ursa Major, Canes Venatici, Coma Berenices, the preceding leg of Bootes, and the head, wings, and shoulder of Virgo." "In this region," adds Sir John Herschel, "occupying but about one-eighth of the whole surface of the sphere, one third of the entire nebulous contents of the heavens are congregated. On the other hand, they are very sparingly scattered over the constellations Aries, Taurus, the head and shoulders of Orion, Perseus, Camelopardalis, Draco, Hercules, the northern part of Serpentarius, the tail of Serpens, that of Aquila, and the whole of Lyra." In the southern heavens a somewhat more uniform arrangement exists, except where the nebulæ congregate within the limits of the Magellanic Clouds, where an even greater richness of distribution prevails than in Virgo on the northern heavens.

Sir John Herschel was the first to suggest the exhibition of the minutiæ of nebular distribution by means of a process of isographic charting, and he invented a plan of charting for the purpose. The present writer distributing the nebulæ over such a chart, in accordance with their actual distribution over the heavens, has been led to recognise the existence of streams of nebulæ over parts of the southern heavens corresponding to the two remarkable star streams compared by the ancients to the river Eridanus, and to a stream of water from the can of Aquarius. In the charts exhibiting this feature, only the nebulæ included in Sir John Herschel's earlier lists were introduced. But Mr Cleveland Abbe having arranged, in a suitable manner, the nebulæ belonging to Sir John Herschel's more complete list, separating the objects classed by Sir William Herschel as nebulæ, properly so called, from clusters, &c., the present writer availed himself of the opportunity to form new charts, not only on the polar isographic projection of Sir John Herschel's, but on two equatorial isographic projections. It was interesting to notice how completely the evidence given by the chart formed from this full list corresponded with the evidence given by the former chart.—*Monthly Notices of the Astronomical Society*, vol. xxix.

The general conclusions resulting from these charts are that—

1. The nebulæ show a marked avoidance of the galactic zone.

2. The northern nebulæ form a somewhat irregular group, with but faint indications of stream formation.

3 The nebulæ in the southern heavens show a tendency to gather into streams with rich extremities—the very converse of the northern arrangement, the borders of the great northern cluster being sparsely strewn with nebulæ

4 The southern streams of nebulæ converge upon the Magellanic clouds

These laws apply to the "nebulæ properly so-called" of Sir William Herschel Clusters, on the other hand, as also planetary nebulæ, and irregular nebulæ (presently to be further considered) show a *preference* for the Milky Way as marked almost as the *avoidance* of this zone in the case of irresolvable nebulæ And, further, it is noteworthy that taking the nebulæ in classes according to their resolvability, we find, with gradually diminishing resolvability, a gradually diminishing preference for the Milky Way, then neutral dispersion, and finally a gradually increasing avoidance of that zone

It is difficult to explain these relations on any theory which does not include the nebulæ of all orders as part and parcel of the sidereal system Sir William Herschel, indeed, was long since led to speak indirectly in favour of such an association, when he remarked that any theory of the universe to be complete must take into account the withdrawal of the nebulæ from the galactic zone In thus implying his belief that that withdrawal is not accidental, he was in effect implying a real association between the sidereal and nebular systems

Irregular and Globular Clusters of Stars These objects differ much in character Amongst the irregular clusters we find many degrees of richness But they are for the most part less condensed than globular clusters, and they fail especially to show marked signs of central condensation "Sir William Herschel," says his son, "regards them as globular clusters in a less advanced stage of condensation, conceiving all such groups as approaching by their mutual attraction to a globular figure, and assembling themselves together from all the surrounding region, under laws of which we have, it is true, no other proof than the observance of a gradation by which their characters shade into one another, so that it is impossible to say where one species ends or the other begins"

Resolvable Nebulæ These objects differ from clusters in having generally no visible outlying branches These appendages we are not to consider as necessarily non existent, even where the most powerful telescope fails to reveal them As Sir John Herschel justly remarks, 'It is under the appearance of objects of this character that all the greater globular clusters exhibit themselves in telescopes of insufficient optical power to show them well, and the conclusion is obvious, that those which the most powerful can barely render resolvable, and even those which, with such powers as are usually applied show no sign of being composed of stars, would be completely resolved by a further increase of optical power In fact this probability has almost been converted into a certainty by the magnificent reflecting telescope constructed by Lord Rosse, which has resolved or rendered resolvable multitudes of nebulæ which had resisted all inferior powers" Most of the resolvable nebulæ are circular in form, and it is a most striking circumstance that nearly all oval nebulæ are much more difficult to resolve than circular ones, so that most of the *irresolvable nebulæ* next to be considered exhibit this peculiarity of figure

Irresolvable Nebulæ These objects form the most remarkable of all the orders of nebulæ They include three principal varieties of form, *elliptic*, *spiral*, and *irregular* But the irregular nebulæ, though forming a sub division of the irresolvable nebulæ, require to be classed separately on account of the striking peculiarities which distinguish them from other irresolvable objects The oval nebulæ are of all orders of ellipticity, down to a spindle shaped or even linear figure They all exhibit a greater or less degree of condensation towards the centre, and it is further noteworthy that "the internal strata approach more nearly than the external to the spherical form" Annular nebulæ are "among the rarest objects in the heavens" They consist of a ring of light, having a dark centre A remarkable object of this class lies about midway between the stars β and γ Lyræ The ring is slightly elliptical, and in telescopes of great power the dark space within the ring is seen to be in reality filled with a very faint light Other ring nebulæ have a very elongated figure, the vacuity appearing so narrow as to resemble a dark line

Planetary Nebulæ These are among the most remarkable objects in the heavens They present a disc of faint light, the outline of the disc being sometimes defined with singular clearness, at others slightly softened off The light of the disc is sometimes uniform, while in other cases a peculiar uniform mottling or *curdling* can be recognised There are but few of these objects in the heavens, only about 25 having been yet discovered, and of these three fourths are in the southern heavens Sir John Herschel remarks on the blue colour of some of these objects, a peculiarity accounted for by the appearance of the spectra of those planetary nebulæ which have hitherto been submitted to spectroscopic analysis Sir John Herschel remarks respecting one of the largest of the planetary nebulæ (situated not far from the star β Ursæ

Majoris) that "its apparent diameter is 2′ 40″, which, supposing it placed at a distance from us not more than that of the star 61 Cygni, would imply a linear diameter seven times greater than that of the orbit of Neptune. The light of this stupendous globe," he adds, "is perfectly equable (except just at the edge, where it is slightly softened) and of considerable brightness. Such an appearance would not be presented by a globular space uniformly filled with stars or luminous matter, which structure would necessarily give rise to an apparent increase of brightness towards the centre in proportion to the thickness traversed by the visual ray. We might, therefore, be inclined to conclude its real constitution to be either that of a hollow spherical shell or of a flat disc, presented to us (by a highly improbable coincidence) in a plane precisely perpendicular to the visual ray." The researches made with the great Rosse telescope gives to the planetary nebulæ an aspect altogether different from the mottled or uniform discs seen by the Herschels. The whole surface of the disc is traversed by strange branches and sprays of faint light, giving to the disc in one instance an appearance somewhat resembling the face of some uncouth monster.

Double Nebulæ. Such objects are occasionally to be met with. In fact Sir John Herschel remarks that "all the varieties of double stars, as to distance, position, and relative brightness, have their counterparts in double nebulæ; besides which, the varieties of form, and gradation of light in the latter afford room for combinations peculiar to this class of objects." He expresses his opinion that the components of these double systems are beyond all question physically associated, and he adds (what will be admitted at once as true, if only the nebulæ are indeed to be regarded as external galaxies), that "nothing more magnificent can be presented to our consideration than such combinations. Their stupendous scale, the multitude of individuals they involve, the perfect symmetry and regularity which many of them present, the utter disregard of complication in thus heaping together system upon system, and construction upon construction, leave us lost in wonder and admiration at the evidence they afford of infinite power and unfathomable design."

Spiral Nebulæ. These objects now form a class by themselves. Their true nature was not, in the first instance, recognised. For example the nebula 51 Messier, as seen by Sir William Herschel, with an 18-inch reflector, presented the appearance of a large bright globular nebula, very unequally bright in different parts, and divided along about two fifths of its circumference into two laminæ, "one of which appeared as if turned up towards the eye out of the plane of the rest." It was this peculiar appearance which led Sir William Herschel to regard this particular nebula as a galaxy resembling the sidereal system, to which system, as we know, his researches had led him to assign the figure of a cloven disc. But in the great telescope of Lord Rosse the aspect of the object is wholly altered. What had appeared as an upraised lamina, was now found to be the coil of an enormous spiral. Lord Rosse detected several other spirals, and Mr Lassell with his fine four-feet mirror at Malta has added importantly to the list of these interesting objects.

Nebulous Stars. Nebulæ are often found in close association with stars. We may find, for example, a bright star centrally situated within a circular nebula, or two bright stars apparently associated in as close a manner with a double nebula, or again, a pair of double stars severally associated with two well defined nebulæ close enough together to seem to form a pair. It is not easy to regard such associations as accidental, and accordingly we find that Sir William Herschel was led to adopt with respect to nebulæ of this order, a theory wholly distinct from that by means of which he explained the clustering resolvable and irresolvable nebulæ. He regarded these objects as in reality stars in process of formation, the nebulous matter gathering towards a centre, and the whole object thus presenting the appearance of an unformed sun with nebulous surroundings. It seems difficult, however, in the present state of our knowledge to accept this view without extending the law of association to other objects, in fact to nearly all the known orders of nebulæ, stellar or gaseous.

Irregular Nebulæ. These are perhaps the most remarkable objects in the heavens. They are altogether unlike all the forms of nebula yet considered, consisting apparently of fantastic convolutions and folds of nebulous matter, extending without any visible law of arrangement throughout enormous regions of space. "No two of them can be said to present any similarity of figure or aspect," says Sir John Herschel, though one may perhaps make an exception in favour of the great nebula round Eta Argûs and the nebula in Dorado, which certainly seem to have some features in common. With the exception of the last-named nebula, all the irregular nebulæ lie in or near the Milky Way, that which lies farthest from the galaxy being the great nebula surrounding the sword handle of Orion. "But this very situation," says Sir John Herschel, "may be adduced as a corroboration of the general view which this principle of localisation suggests. For the place in question is situated in the prolongation of that faint offset of the Milky Way which has been traced from α and ϵ Persei towards Aldebaran and the

Hyades, and also in the zone of great stars which seems to form an appendage of that stratum" He adds that it would seem to follow from this, almost as a matter of course, that they must be regarded as outlying, very distant, and as it were detached fragments of the great stratum of the galaxy Now it is of extreme importance to notice that while, on the one hand, this view, that the irregular nebulæ are associated with the galaxy, presented itself to so skilful an astronomer as "almost a matter of course," the results of spectroscopic analysis show that the idea of great distance associated by Sir John Herschel with these nebulous masses is not consistent with what we know of the nature of their structure We are certain that whether these masses are more distant or not than the stellar parts of the galaxy, this zone would not, as Sir John goes on to suggest, by mere increase of distance, come to exhibit the same characteristics as the irregular nebulæ For the galactic masses would never appear as gaseous masses under spectroscopic research, let their distance be increased ever so much, and it is as gaseous masses that the irregular nebulæ have come to be regarded It seems, indeed, far more reasonable to suppose with Sir William Herschel that the great nebula in Orion is nearer than the stars seen in the same field of view with it, than to imagine that its nebulous aspect is due to vastness of distance It is, indeed, well worthy of careful notice that the irregular nebulæ are found always in association with parts of the heavens where lucid stars are richly distributed So that it seems conceivable that we recognise in these regions, owing to their relative proximity the existence of matter which in reality surrounds also many of the more distant groups o stars There are four great regions of irregular nebulous matter, that of Orion, that of Argo that of Cygnus, and that of Sagittarius, the nebulæ belonging to the two former regions bein the more remarkable, though all four groups present features of special interest, and promise t afford the thoughtful astronomer information of great value respecting the structure of th universe

The great nebula which surrounds the star η Argûs, merits a separate account, as it exhibit certain characteristics wholly distinct from those which, so far as has yet been seen, belon to other objects of the same class The star with which this nebula is associated is one o a very remarkable character (see *Stars, Temporary*), and the nebula itself seems no less variabl than the star It may seem unduly speculative to assert that this peculiarity, that the mos remarkable variable star in the heavens thus seems to be associated with the most remarkabl variable nebula, is of itself a proof of real association There are, however, other signs o association which seem to confirm this view We follow Sir John Herschel's account of th position and character of the nebula "The whole is situated," he tells us, "in a very rich an brilliant part of the Milky Way, so thickly strewn with stars that in the area occupied by th nebula not less than 1200 have been actually counted" Respecting these he asserts that the have obviously no connection with the nebula, a view which may be regarded as fairly open t question where no proof in its favour can (from the nature of the case) be offered Then h proceeds, "It is not easy for language to convey a full impression of the beauty and sublimity o the spectacle which this nebula offers, as it enters the field of view of a telescope fixed in righ ascension, ushered in as it is by so glorious and innumerable a procession of stars, to which i forms a sort of climax" The discovery that the nebula is variable, and that the variation is o a very marked character, opposes itself strikingly to Sir John Herschel's conclusion that i "looking at the Argo nebula we see through and beyond the Milky Way, far out into spac through a starless region, disconnecting it altogether with our system" The scale on whic the nebula is constructed is increased enormously on this view, and the variability of th nebulous masses becomes a proportionately more amazing problem Thus M Le Sueur, of th Melbourne Observatory, in announcing his discovery that the nebula is really variable, expresse his belief that it lies *nearer* to us than the stars seen in the same field of view More recentl however, finding that the spectrum of the star Eta Argûs exhibits the same bright lines as t nebula, he has expressed the opinion that the star is probably in some way associated with th nebula, a view which the present writer had put forward two years before for other reasons

Variable and Temporary Nebulæ Other nebulæ besides that around the star Eta Argûs hav been found to be variable Some nebulæ have, indeed, vanished altogether from view O October 11, 1852, Mr Hind discovered a nebula in Taurus, which had not before been seen and d'Arrest re-observed this nebula in 1855 and 1856 But in October 3d, 1861, d'Arr could not find it "I cannot find a trace of it," he says, "though it was observed once an again by me in the years 1855 and 1856, and its place four times determined" At the close o 1861 the nebula could just be seen by M Otto Struve, with the great refractor of the Pulkow Observatory, and in March 1862 it was comparatively a bright object Another nebula wa discovered by Mr Tuttle, on September 1, 1859, which was so brilliant and remarkable th d'Arrest thinks it could not possibly have been overlooked by the Herschels had it been s conspicuous when they swept the heavens with their great reflectors. In the Pleiades, "ce

tainly the last place in the heavens," says Sir John Herschel, "in which the discovery of a new nebula would have been expected," a large bright nebula was detected by Tempel, on October 19, 1859. Mr Hind has also often suspected nebulosity about some of the outlying stars of the Pleiades Mr Pogson observed, on May 28, 1860, that in the place occupied *previously* by the bright and very conspicuous nebula 80 Messier, a star of the seven eighth magnitude had made its appearance On the 9th of May this nebula had presented its usual aspect On June 10th the stellar appearance had passed away, but the nebula was still unusually bright and condensed Professor Luther and M Auwers had also noticed the change as early as May 21st, rating the star then as of the six-seventh magnitude On June 10th the nebula had nearly vanished

Certainly such observations as these lend little encouragement to the theory that the nebulæ are external star-systems resembling our own sidereal system in character.

NEBULAR HYPOTHESIS A theory by which Laplace endeavoured to account for the principal features of the solar system, as due to a regular process of development by which that system has reached its present condition The Newtonian theory accounts for certain distinctive features of the solar system, but leaves others unexplained We can by means of the law of gravitation interpret the fact that the planets revolve in elliptic orbits, that a line drawn from any planet to the sun traces out equal areas in equal times, and that the cubes of the mean distances of the planets are severally proportional to the squares of the periodic times But we have no explanation, under the Newtonian hypothesis, of other characteristic peculiarities of these orbital motions Gravity tells us that the planetary orbits, if nearly circular at one time, would continue so for an indefinite period, but not how it has come to pass that they *are* nearly circular Gravity tells us, again, that the planetary orbits, if at any one time nearly approximating to a single plane, would continue to exhibit that peculiarity for an indefinitely long period, but not why those orbits came to have that special attribute Again, gravity does not explain why all the planets should travel in one direction around the sun, nor why it should be a general characteristic of the satellites' motions that they should take place in one direction, and that direction the same as that in which the planets revolve around the sun, nor, lastly, does gravity explain why the planets should rotate on their axis in the same direction, and that direction still identical with the direction of the planetary revolutions Now, unless we are to assume the direct action of a First Cause as operative in the matter, we are compelled by the laws of probability to recognise the fact that these relations indicate the operation of law Whether we are justified in regarding any phase of the processes of nature as representing the direct action of the Creator, whether, in fact, the range of our researches can be expected to indicate to us the time when (in our own system or any other) such a cause was in operation, is a question to which different minds will give different answers But even those most jealously anxious lest anything men may conclude should seem to detract from a just estimate of the Almighty's attributes, will admit the possibility that the action of a First Cause is not *necessarily* to be associated with the formation of the solar system, but may, for anything we can tell to the contrary, belong to an antecedent epoch infinitely remote. Thus free to consider at least the possibility that the observed peculiarities of the solar system may be due to the nature of the processes by which it was developed from some former condition, let us consider how far Laplace's hypothesis on the subject serves to account for the observed relations.

According to the nebular hypothesis the solar system originally consisted of a vast rotating nebulous globe extending far out in space beyond the orbit even of distant Neptune This rotating globe, parting with its heat, contracted gradually from its original dimensions As this process of contraction proceeded the rotatory motion increased, and at length became so great that the outermost parts were no longer retained by their gravitation towards the centre Thus a zone or ring of nebulous matter was thrown off, then as the globe continued to contract another zone was formed in a similar manner, and so the process continued, a succession of zones or rings being formed in the equatorial plane of the rotating globe "These zones," says M Pontecoulant, in expounding the views of Laplace, "must have begun by circulating round the sun in the form of concentric rings, the most volatile molecules of which formed the outer part and the most condensed the inner If all the nebulous molecules of which these rings are composed had continued to cool without disuniting, they would have ended by forming a liquid or solid ring But the regular constitution which all parts of the ring would require for this to happen, and which they must also have retained while cooling, would make this result extremely rare" Generally a ring would break into several parts, which would continue to circulate round the sun with almost equal velocity "At the same time in consequence of their separation they would acquire a rotatory motion round their respective centres of gravity; and as the molecules of the outer part of the ring, that is, those farthest from the sun, would have the greatest velocity, the resulting rotatory motion would necessarily be in the same

direction as the orbital motion" The theory then goes on to show how in the majority of instances the fragments of a broken ring would coalesce into a single planet, how it might happen that the several fragments would continue to travel independently round the sun as in the zone of asteroids, while the rings of Saturn are regarded, according to this theory, as the solitary instance in which a ring (in this case belonging to a subordinate contracting nebulous mass) has not broken at all into fragments, but owing to the nice adjustment of all its parts has remained to attest the nature of the processes by which in long past ages the solar system wrought its way to its present condition It will easily be seen how the contraction of the several nebulous masses which were the embryos of the planets might result in the formation of systems resembling the parent system, as in the case of the exterior planets, or in the formation of such orbs as circle within the zone of asteroids, amongst which the earth alone has a dependent satellite

Ingenious as this hypothesis is, it yet presents several difficulties which cannot be overlooked It accounts well for the features of regularity presented by the solar system—too well indeed, since it would lead us to expect a greater degree of regularity than we actually find It is difficult to see how, under such a process, there should result those departures from exact circularity, or from exact coincidence of orbital motion with the plane of the ecliptic, which we actually recognise within the solar system And if there is one region where, according to Laplace's theory, we ought to find more perfect symmetry than elsewhere, it is precisely in that zone of asteroids, amongst the members of which we find the greatest departures both from the ecliptic plane and from circularity of orbital motion

Yet, further, the theory of Laplace would lead us to expect a difference of elementary constitution between the planets travelling at great distances from the sun and those nearest to him It was indeed urged by him that the actual difference as respects specific gravity between the planets exterior to the zone of asteroids, and those travelling within that zone, was in accordance with, and might be regarded as tending to establish, his hypothesis But there is no regular sequence in the specific gravities of the planets, whether of the outer or of the inner family, and his theory requires such a sequence We now know also, from what the spectroscope has taught us about the sun and planets, that the elementary constitution of all the members of the solar system is probably identical

Yet further, the retrograde motions of the satellites of Uranus, and the assumed retrograde rotation of that planet, seem to oppose themselves very strongly to our belief in an hypothesis which suggests no possible origin of any motions opposed to the direction of rotation of the original nebulous globe

While these considerations tend to render the hypothesis of Laplace as presented by him at least doubtful, if not absolutely untenable, they yet are not of such a nature as to preclude the belief that the solar system has reached its present condition by a process of development

A mode of inquiry which does not seem to have suggested itself to Laplace, and which, in any case, he would have had no means of applying effectually, seems to promise a more complete interpretation of the characteristics of the solar system, than the
to establish There are processes still at work within the solar syste[illegible]
associated with the genesis itself of that system The sun, the earth, and all the planets are undoubtedly *growing*, though their present rate of growth may be indefinitely small compared with the rate at which (on any reasonable hypothesis of development) they must be supposed to have first assumed independent existence We know that meteoric masses are falling in enormous numbers upon the earth, and that they must fall in numbers inconceivably greater upon the sun, while the very nature of the meteoric orbits proves, beyond all possibility of question, that other planets, with all their dependent satellites, the zone of asteroids—nay, even the rings of Saturn—must receive in greater or less degree these contributions from interplanetary, and also (remembering the wide range of the sun's influence, and his proper motion within the sidereal system) even from interstellar space.

Now, the mere fact that at present the sun, and the family circling round him, enormously outweigh the combined mass of all the meteoric systems within the limits of the sun's attraction, by no means proves that, in long past ages, the direct reverse may not have been the case One may well conceive that of old the solar system presented, *not* a central sun, but a tendency to central aggregation within a group of widely extended meteoric systems—*not* subordinate orbs like the planets, but a tendency to subordinate aggregations Looking yet further back, and conceiving the solar system in its embryonic condition to have presented myriads of millions of meteoric systems, travelling in all possible directions, and in orbits having every degree of eccentricity under the influence of the laws of gravity (as they would affect a system of that order), we can readily see how a general preponderance of motions in one direction and about one plane, though it might be masked at first, would in the long run assert its influence

Collisions continually occurring amongst the members of the meteoric systems, would tend to eliminate the more eccentric and inclined motions, while the motions in a direction opposed to the general set of the system, would also in the long run disappear, at least in regions of aggregation.

Now, in considering the ultimate condition towards which these processes would tend, we must not lose sight of the circumstance that, so soon as a well marked central aggregation was formed, its neighbourhood would be the scene of all the most rapid motions within the complex scheme of systems. This aggregation was the embryon sun of the scheme, and in its neighbourhood were the perihelia of all the systems, precisely as now the relatively puny meteoric systems still remaining have their perihelia mostly within the orbit of the earth. Hence near the central aggregation subordinate aggregations would form with difficulty, and even when formed they would grow slowly, because of their small power to influence meteoric systems travelling swiftly past them. It could only be at a considerable distance from the central aggregation that the meteoric motions would be so far reduced as to favour the formation and growth of subordinate aggregations.

We see in these considerations a general explanation of the orders of magnitude observed among the primary members of the solar system. We see why the bodies near the sun are relatively small, while those farther from him are relatively important. Taking the orbit of Jupiter as the region where the quantity of material and the general rate of meteoric motion were such as to favour to a maximum degree the formation of a subordinate system, we see that between this great secondary aggregation and the central one, all the subordinate aggregations would be relatively minute, and would attain their fullest development in the mid region; and, accordingly, we see Venus and the earth more important than Mercury, on the one hand, or Mars and the zone of asteroids on the other. Outside the orbit of Jupiter we should expect to find massive orbs, with complex subordinate systems, because the formation of subordinate aggregations would be favoured by increase of distance from the sun. But the quantity of material would diminish continually towards the outskirts of the system, so that the inferiority of Saturn, and still more that of the distant planets Uranus and Neptune, to the giant bulk of Jupiter, receives an explanation.

Further, we might look, according to this hypothesis, for a closer degree of association between the equators of the planets and the planes of motion of the satellites, with the medial plane of the system, according as the bulk of a planet rendered it probable that among the meteoric systems which had formed it there was a great preponderance of motions belonging to the general set of the scheme. Accordingly, we find that, among the minor planets which travel within the zone of asteroids, the inclination of the rotation-plane is greater in the case of Mars than in that of the earth (the inclinations of Mercury and Venus being unknown), while proceeding to the family of major planets, we find the inclination of Jupiter's equator very small indeed (only $3\frac{1}{2}$ degrees), that of Saturn's considerable, and the inclination of the equator of Uranus absolutely abnormal, if one can judge (as is probable) from the motions of his satellites. Neptune's satellite seems also to revolve in a retrograde manner, but as yet observation has not certainly determined the relations of this distant system.

It is noteworthy of this hypothesis that, according to it, all the planets and satellites would be constituted of the same elementary materials, but the larger planets would be originally formed by bodies coming into collision with far greater force than those forming the smaller planets. Hence the larger planets would be raised to a far more intense degree of heat. Their specific gravity might on this account be expected to be smaller than that of the minor planets. On the other hand, the satellites, and such very small members of the system as the asteroids, would be formed by bodies coming into collision with velocities relatively so minute that complete fusion might not be expected to result in all cases, and a low mean specific gravity (as observed in the case of our own moon and the satellites of Jupiter) might result from the existence of vast cavities in the interior of these bodies.

NEBULAR SPECTRA. Mr Huggins has discovered (*Phil. Trans.*, 1868, p. 529) that the irresolvable nebulæ show spectra, consisting of three or four isolated bright lines, much nearer together than those in the cometary spectra. From an examination of about seventy nebulæ, Mr Huggins finds that nearly one third give spectra of this character, showing that they are gaseous, the light of the remaining being spread out by the prism into a spectrum which is apparently continuous. Of the bright lines, one appears to be due to hydrogen, and another to nitrogen, whilst the middle line has not yet been identified. (See *Spectrum*.)

NEEDLE, MAGNETIC. Primarily applied to a magnetised sewing or knitting needle; but any straight magnet is called a magnetic needle according to the present usage of the term. The term is not unfrequently employed to designate magnetic bars of many pounds weight.

NEGATIVE AXIS OF CRYSTALS See *Positive Axis of Crystals, Crystals, Optic Axis of*

NEGATIVE CONDUCTOR. The part of an electric machine at which negative electricity is collected In an ordinary friction electric machine it consists of a brass cylinder, to which the rubbers are attached (See *Electric Machine*)

NEGATIVE EYE-PIECE This is the form of eye-piece most used for telescopes and microscopes It consists of a field glass and an eye glass, each plano convex, the plane surfaces being turned towards the eye, and the distance between them being half the sum of their focal lengths The focal length of the field-glass is three times that of the eye glass The focus of this eye-piece is between the two glasses, and it is therefore not so well adapted for use with micrometers as the *positive eye-piece* (See *Positive Eye-piece, Micrometer Eye piece, Eye piece*)

NEKKAR (Arabic) The star β of the constellation Bootes

NEPTUNE (*Neptunus*) In astronomy, the most distant of all the known planets, and eighth in order of distance from the sun Neptune travels at a mean distance of no less than 2,745,998,000 miles from the sun, his greatest distance being 2,771,190,000, his least 2,720,806,000 Since the earth's mean distance from the sun is 91,430,000 miles, it follows that the distance of Neptune from the earth varies from about 2,863,000,000 to about 2,629,000,000 miles The eccentricity of his orbit is small, amounting only to 0 008720 The inclination of the orbit to the plane of the ecliptic is $1^\circ\ 47'$ Neptune is somewhat larger than Uranus, his diameter being estimated to be about 37,300 miles, though, in the case of a planet which is always at so enormous a distance from the earth, no confident reliance can be placed on such measurements The volume of Neptune exceeds that of the earth about 105 times, but his density being only 0 16 (the earth s as 1), his mass exceeds the earth only about $16\frac{3}{4}$ times We know nothing about his rotation upon his axis or the position of his axis

The discovery of Neptune must be regarded as one of the greatest triumphs yet achieved by the Newtonian astronomy The planet Uranus was found to be following a path not strictly accordant with that assigned to it by astronomers, insomuch that Bouvard, to whom astronomy owes the calculation of excellent tables of Jupiter, Saturn, and Uranus, was led to express his belief that some external planet disturbs the motions of Uranus The French astronomer Leverrier was led to examine this subject at length He considered all the various explanations available, and finally arrived at the conclusion that some planet external to Uranus must, as Bouvard had suggested, be in question In the meantime, Adams, of Cambridge, had boldly adopted this solution of the question, and commenced the arduous labour of calculating, from the observed perturbations of Uranus, the position of the disturbing planet Leverrier and Adams worked simultaneously at the solution of this noble problem, but Adams retained the start which his bold guess had given him, completed his labours first, described his results in a letter to Mr Airy, and afforded full means for the complete solution of the problem and the detection of the planet Nay, the planet actually was observed by Challis as a consequence of the instructions he received, though he was led to postpone the requisite examination of his results in favour of other observations which happened to engage his attention. A month after the Cambridge Observatory had been set upon the track of the planet—to wit, on August 31, 1846—Leverrier published his results, and pointed out the place where the planet was to be looked for The Berlin astronomers received information on the matter on September 23d, 1846, and on the same evening detected the planet It is customary to ascribe their success to the accuracy of the Berlin star maps, while the failure of our English observers is attributed to the want of accurate maps The real fact is, that the Berlin observers were impressed with a full sense of the importance of the communication which had reached them, and, as they recognised the planet by its aspect, would in all probability have succeeded in their search even though they had had no maps to guide them, seeing that the motion of the planet would, in a day at the outside, have proved its planetary nature By unfortunate negligence on our part, was a discovery which would have adorned throughout all ages the fame of English astronomy, suffered to pass into the hands of Continental astronomers, or to remain as a subject of contention and ill-feeling whensoever the just claims of our distinguished countrymen should be asserted.

It is important to notice that in nearly every treatise on popular astronomy in which the perturbations of Uranus by Neptune are considered, a mistake is made involving a perfect misapprehension of the principles of planetary perturbation A figure is introduced intended to exhibit the perturbing action of Neptune over an interval including the passage of Uranus from superior to inferior conjunction with Neptune, and over the whole of this passage Neptune's attraction is represented as accelerating the motion of Uranus The reverse is the case so far as a large portion of this arc is concerned. Neptune attracts the sun as well as Uranus,

nor, in this case, does the excess of the sun's mass over that of Uranus affect the question It is only the excess or defect of Neptune's action on Uranus which perturbs that planet

We know very little of the physical habitudes of Neptune, even the most powerful telescopes being ineffectual to exhibit any signs either of belts or of the rotation of the planet upon its axis It has been supposed that the planet rotates in a direction contrary to that observed among the other planets, though the only evidence on this point has been derived from the motion of the satellite of Neptune, and the nature even of this motion has not been satisfactorily established.

NEWCOMEN'S ENGINE See *Steam Engine*

NEWTONIAN SYSTEM The name given to the modern system of physical astronomy as distinguished from the modern system of formal astronomy, which is usually called the *Copernican System*, but is more correctly named the *Keplerian System*

NEWTONIAN TELESCOPE This is an improvement by Sir Isaac Newton on the Gregorian Reflecting Telescope The concave speculum is not perforated It reflects the light from an object upon a plane speculum inclined 45° to the axis of the instrument. This reflects the rays to the side of the tube, where a hole is cut to receive the eye-piece (See *Telescope*)

NEWTON'S RINGS When a convex lens of very long focus is pressed against a plane surface of glass the thin film of air enclosed between the two surfaces reflects light in a series of rings coloured by interference (See *Interference, Thin Films, Colours of*) These colours were first examined by Sir Isaac Newton, and are hence called Newton's rings The order of colour follows that given under the heading *Newton's Scale of Colours* The thickness requisite to produce a certain colour varies with the refractive index of the substance Thus, supposing a thickness of 14 millionths of an inch of air were required to produce blue, this colour will be given by a thickness of 10½ millionths of an inch of water and 9 millionths of an inch of glass, the necessary thickness diminishing as the refractive index increases

NEWTON'S SCALE OF COLOURS A series of colours produced when light is reflected from an excessively thin film, gradually increasing in thickness The scale, commencing with the least thickness, at which the film reflects no light at all, but appears black, is as follows, the thicknesses (for air) being given in millionths of an inch —

1st order.	Black,	0 50
	Blue,	2 40
	White,	5 25
	Yellow,	7 11
	Orange,	8 00
	Red,	9 00
2d order.	Indigo,	12 83
	Blue,	14 00
	Green,	15·12
	Yellow,	16 29
	Orange,	17 22
	Red,	18 33
	Dusky Red,	19 67
3d order	Purple,	21 00
	Indigo,	22 10
	Blue,	23 40
	Green,	25 20
	Yellow,	27 14
	Red,	29 00
4th order	Bluish Green,	34 00
	Yellowish Green,	36 00
	Red,	40 33
5th order	Sea Green,	46 00
	Pale Red,	52 50
6th order.	Blue,	58 75
	Red,	65 00
7th order	Greenish Blue,	71 00
	Reddish White,	77 00

(See *Interference of Light*)

NICKEL A metallic element, bearing great similarity to cobalt, and intimately associated with it in nature Atomic weight 59 Symbol Ni It was discovered by Cronstedt in 1751, and its name is derived from the German Kupfernikel, or false copper, a term applied by the miners to the arsenide of nickel, a brass coloured substance which they mistook for copper pyrites The methods of separating nickel from arsenic and cobalt are complicated, and are effected in what is called the wet way, that is to say, by solution in liquids and precipitation. A pure compound having been thus obtained, it is reduced by heating in a furnace with charcoal, or by reduction by carbonic oxide After fusion, pure nickel is silver white, ductile, and malleable, it melts at about the same temperature as iron, and, according to Deville, it surpasses iron in tenacity, its specific gravity is 8 279. It is magnetic at ordinary temperatures, but loses this property at the temperature of an oil bath Its principal use in the arts is in the manufacture of German silver, an alloy of nickel and copper (See *Alloys*) Nickel forms two oxides, the *protoxide* NiO, and the *peroxide* Ni_2O_3 The protoxide is a dense grayish green powder, which dissolves in acids forming salts. The *protochloride of nickel* forms golden yellow scales,

which dissolve in water to a fine green colour The principal sulphide of nickel is the *protosulphide* NiS. In the native state it has a brass yellow metallic lustre. The hydrated protosulphide is a dark brown insoluble powder For the different salts of nickel, see the respective acids.

NICOL PRISM A prism of Iceland spar so constructed that only one polarised ray can pass through it It is named after the discoverer A rhomb of Iceland spar is carefully sawn into two parts along a plane perpendicular to the plane of the larger diagonal of the base, and passing through the obtuse angled corners The two halves are then reunited by means of Canada balsam in exactly the same position in which they were before being cut The principle of its action is this, the refractive index of Canada balsam (1 549) is less than the ordinary index of Iceland spar (1 654), but greater than its extraordinary index (1·483). A ray of common light entering the Nicol prism at one end, is divided into two oppositely polarised rays, the ordinary and the extraordinary When these rays meet the Canada balsam cement, the ordinary ray undergoes total reflection from this surface, and is sent out of the field at the side, whilst the extraordinary ray passes through alone The emergent light is therefore polarised in one direction only The Nicol prism may be used either as a polariser or analyser When employed in delicate optical measurements an anomaly is frequently remarked the azimuths of extinction do not occur at a distance of 180° The error can amount to several tenths of a minute This error would be fatal to the use of the Nicol's prism if the cause could not be discovered, diminished, and remedied M Cornu first pointed out this cause, and he has given the following explanation —The axis of rotation of the prism, or rather that of the instrument which carries it, does not coincide with the plane of the principal section, hence the ray which traverses it takes different directions in the prism, according to the azimuth, and the polarisation to which it is subject is not parallel to the plane of the optical symmetry of the crystal When the lines of entry and emergence of the prism are quite parallel, it can be regulated by trial, in general, the error will be only alternated and not annulled, but it may be eliminated in proceeding by crossed observations In fact, it is easy to demonstrate by a very simple calculation, and by direct observation, that the error ϵ of the normal azimuth is given by the formula

$$\epsilon = A(z + a);$$

A and e being the constants, z the observed azimuth, it is easy to deduce that the mean of the reading of the azimuths, which should strictly differ by 180°, gives, after the subtraction of 90°, the real azimuth The error is eliminated of its own accord, if we choose for the measurements of the azimuths the mean of two positions of extinction, whether for the analyser or for the polariser (See *Polarisation Plane*)

NICOTINE The active principal of tobacco It is a colourless transparent oil, intensely poisonous, and of a burning taste even when very dilute, it has a strong alkaline reaction, and forms salts with acids It boils at 482° F Tobacco contains it in proportions varying from 2 to 8 per cent, Havannah tobacco containing the smallest amount

NIMBUS See *Cloud*

NIOBIUM See *Columbium*

NITRATES Combinations of nitric acid with bases are called nitrates. For the most part they crystallise readily, they are all soluble in water, and are generally neutral to test paper When heated they readily decompose, evolving for the most part a mixture of oxygen and oxides of nitrogen, heated with combustible bodies they deflagrate violently, and sometimes explode The following are the most important nitrates *Nitrate of Barium* White transparent crystals, having a specific gravity of 3 1848 Formula $Ba2NO_3$ It is prepared by dissolving the native carbonate of baryta in dilute nitric acid, and crystallising It forms regular octahedrons When heated the crystals melt, and at a red heat decompose, leaving a residue of pure baryta. It is tolerably soluble in water, but difficultly so in nitric acid It is used in the arts for pyrotechnic purposes, as it produces an intense green flame when deflagrated with combustible substances *Nitrate of Calcium* A salt which is formed naturally in many parts of the world, and artificially in some countries, by imitating the conditions of nature When heaps of decomposing animal and vegetable matter, mixed with clay, chalk, ashes, &c, and moistened with urine, soap-suds, &c, are exposed to the air for some years, decomposition takes place, and the nitrogenous matters oxidise to nitric acid, which, uniting with the calcium of the chalk, forms nitrate of calcium The solution from the lixiviated mass is mixed with a potassium salt to decompose the calcium salt, and evaporated down, when nitrate of potassium crystallises out. These beds are called artificial nitre beds or *saltpetre plantations*, and are largely employed on the Continent The same conditions which favour the formation of nitrate of calcium in these heaps are frequently present in mortar and plaster, and the nitrate of calcium then effloresces from the

surface of the wall, causing rapid disintegration This is called the saltpetre rot Nitrate of calcium in the pure state forms six-sided prismatic crystals, very soluble in water, and decomposing when heated to redness *Nitrate of Copper* The only nitrate of importance is the normal nitrate ($Cu2NO_3$) which is obtained by dissolving the metal, its oxide or carbonate in nitric acid On evaporating the solution the salt is deposited in blue crystals, containing water of hydration, they are very soluble in water *Nitrates of Iron* Iron forms several nitrates The most important are the normal *ferric nitrate* and the *ferrous nitrate.* The former has the composition $Fe3NO_3\ 18H_2O$ It crystallises in oblique rhombic prisms of a faint lavender blue tint, very soluble in water The ferrous nitrate ($Fe2NO_3$) crystallises in four sided prisms of a faint greenish colour, and very soluble in water An impure mixture of these two nitrates is used in dyeing under the name of iron mordant *Nitrate of Lead* The normal salt has the composition $Pb_2ON_2O_5$, it crystallises in large white octahedrons, soluble in about eight times their weight of cold water, and in much less of hot water There are also many basic nitrates of lead, but they are unimportant *Nitrates of Mercury* Mercury forms two normal nitrates and many basic nitrates, the former need only be described The *mercuric nitrate* ($Hg2NO_3H_2O$) crystallises in bulky deliquescent rhombs, easily decomposed into basic salts on addition of water The *mercurous nitrate* ($Hg_22NO_3\ H_2O$) is the one usually met with, it is formed by digesting excess of metallic mercury with cold nitric acid, it separates in colourless monoclinic crystals which are decomposed by much water into a basic salt For test purposes mercurous nitrate is always dissolved in very dilute nitric acid, a little metallic mercury being added at the same time *Nitrate of Potassium,* called also *nitre* and *saltpetre* (KNO_3) A white inodorous salt of a cooling bitter taste, crystallising in long six sided prisms which are anhydrous and very soluble in water, and readily crystallised therefrom Nitrate of potassium melts below a red heat without farther change, solidifying on cooling to a hard white mass known in commerce as *sal prunellæ* At a red heat oxygen is given off, nitrite of potassium being left, and if the heat is continued nitrogen is evolved with the oxygen When heated with combustible substances deflagration takes place, on this property its use in the manufacture of gunpowder and pyrotechnic mixtures depends Nitrate of potassium is found as a natural product in many parts of the world, where its formation is still going on The conditions necessary for its production have been described above (*Nitrate of Calcium*) They are frequently imitated artificially, the essential requisites appearing to be an abundant supply of ammonia (from the oxidation of which the nitric acid comes), the presence of earthy and alkaline bases, free access of air and a mean temperature not lower than from 65° to 75° F If potash salts are present in the substances used in making the beds, crude nitrate of potassium is at once obtained by lixiviation and crystallising, but if lime compounds are in excess, nitrate of calcium, as before explained, is produced The principal impurity of crude saltpetre is chloride of sodium, which is separated by peculiar methods of crystallisation Nitrate of potassium is also prepared in enormous quantities by decomposing nitrate of sodium with carbonate of potassium or caustic potash, when a double decomposition takes place, and nitrate of potassium is separated by crystallising *Nitrate of Silver* ($AgNO_3$), known also as *lunar caustic, lapis infernalis* A salt crystallising in colourless trimetric crystals very soluble in cold water When mixed with organic matter and exposed to light (see *Actinism*) reduction of silver to the metallic state takes place This property is taken advantage of in photography Nitrate of silver forms insoluble compounds with many kinds of animal matter, and is then gradually reduced to the state of metal, with oxidation of the organic substance, on this account nitrate of silver is used as a caustic, as it rapidly destroys organisation and vitality when applied to the moist surface of the body *Nitrate of Sodium,* called also *Chili saltpetre, Cubic nitre* ($NaNO_3$) A salt crystallising in obtuse rhombohedrons which closely approach cubes, hence the name cubic nitre It is deliquescent in moist air, and dissolves readily in water, it behaves with heat in a similar manner to nitrate of potassium Nitrate of sodium is found in enormous masses in some parts of South America, beds of it several feet thick occurring in the district of Tarapaca, northern Chili, where the dry pampa is covered with it for a space of forty leagues, its principal impurity is chloride of sodium, from which it is separated only with difficulty Owing to the low price of nitrate of sodium, it is largely used in the manufacture of saltpetre, nitric acid, and sometimes it is employed direct for inferior varieties of gunpowder, and also for manure *Nitrate of Strontium* ($Sr2NO_3$). A colourless salt crystallising in octahedrons, soluble in five parts of cold water, at a red heat it decomposes, leaving a residue of caustic strontia It is prepared like nitrate of barium, and when mixed with appropriate combustibles it causes them to burn with an intensely red flame, forming the red fire of the theatres. *Nitrate of zinc,* the normal salt ($Zn2NO_3\ 3H_2O$), crystallises in colourless four sided prisms, deliquescent in the air, and readily soluble in water and alcohol. *Nitrate of Ethyl* (nitric ether, $C_2H_5NO_3$) A colourless liquid insoluble in water, but soluble in all proportions in alcohol, it has a very sweet taste and a strong peculiar odour,

it is inflammable, its specific gravity is 1 112, and it boils at 85°C (185°F) Nitrates of other ethyl radicals exist, but at present they are unimportant, and a mere enumeration of them would occupy far more space than their importance demands

NITRE. See *Nitrates*, *Nitrate of Potassium*

NITRIC ACID (*Azotic Acid*, *Spirit of Nitre*, *Aquafortis*) HNO_3 A colourless transparent liquid of specific gravity 1 52, it freezes at —55°C, forming a mass like butter, it boils at 86°C (187°F), fumes in the air, and when mixed with water it evolves an appreciable amount of heat. Nitric acid is a very powerful oxidising agent, when hot and undiluted it attacks and destroys nearly all organic bodies with copious evolution of red fumes of nitric peroxide, and when somewhat dilute it stains nitrogenous matter a bright yellow colour. It also attacks and oxidises most of the elementary bodies, except gold, platinum, and a few of the rarer metals, the compounds produced are for the most part soluble in water, silicon, tin, antimony, and tungsten forming however insoluble acids The most concentrated acid has so powerful an oxidising action on carbon that it is competent to keep up the combustion of a lump of red hot charcoal plunged into it The industrial uses of nitric acid are very various and important, a mixture of it with hydrochloric acid forms *nitro hydrochloric acid* (*nitro-muriatic acid*, *aqua-regia*), which is used for dissolving gold and platinum With many kinds of organic matter strong nitric acid, if the temperature be kept down, forms what are called nitro substitution products, one, two, or three atoms of hydrogen being removed from the compound, their place being occupied by an equal number of molecules of nitryl (NO_2) Some of these nitro-substitution compounds are of great importance in the arts, thus from benzol (C_6H_6) is formed *nitro-benzol* ($C_6H_5(NO_2)$) which is used in the manufacture of aniline, with phenol or carbolic acid (C_6H_6O) is formed tri nitro phenol, or *picric acid* ($C_6H_3(NO_2)_3O$), from cellulose (cotton, woody fibre, &c, $C_6H_{10}O_5$), we get *tri-nitro-cellulose* ($C_6H_7(NO_2)_3O$) or *gun cotton*

NITRIC ETHER See *Nitrates*, *Nitrate of Ethyl*.

NITRO-BENZOL See *Benzol*, *Nitric Acid*

NITROGEN (νιτρον, nitre, and γενναω, to generate *Azote*, *a*, without, and ζωη, life) An element discovered by Rutherford in 1772 Atomic weight 14 Symbol N. It is a permanent gas, constituting about four fifths of the volume of the atmosphere It is colourless, uncondensible, tasteless, inodorous, and neutral to vegetable colours It dissolves in cold water to the extent of 1½ per cent It is incombustible, and does not support respiration, although not irrespirable It is not poisonous, but kills from the absence of oxygen It acts in the atmosphere principally as a diluent to restrain the too energetic action of the oxygen (See *Atmosphere*) In the free state, nitrogen exhibits no marked properties, although it enters into the composition of the strongest acids, the most deadly poisons, the most brilliant colours, the most valuable medicines, and the most destructive explosives, appearing to give energy by its presence, and affording a strange contrast to its absence of character in the free state Nitrogen is generally procured from the atmosphere by burning a piece of phosphorus under a bell jar standing over water The phosphorus unites with the oxygen, forming phosphoric acid, which is readily soluble in water, leaving the nitrogen behind There are many other ways of forming nitrogen, but these need not be detailed here Nitrogen forms the first term of the triad group of elements, the others being phosphorus, arsenic, antimony, bismuth, and vanadium Nitrogen unites direct with the metals titanium, tantalum, and tungsten These are said even to burn in it, and, under some circumstances, it unites direct with hydrogen, oxygen, and carbon

NITROGEN, IODIDE OF See *Iodine*

NITROGEN, SPECTRUM OF The spectrum of nitrogen in a Geissler's tube is somewhat complicated When not ignited much beyond its point of incandescence, a series of bands is seen tolerably equidistant, sharp at one side, and shading off towards the violet end If the temperature is increased by introducing a Leyden jar into the circuit, the spectrum changes altogether, and is now composed of fine bright lines Plucker has called these spectra of the *first order* and spectra of the *second order* The change takes place quite suddenly, and is attributed to the change of allotropic condition of the gas Other gases besides nitrogen are found to exhibit similar phenomena

NITRO-GLYCERIN. A light, yellow, oily liquid, of specific gravity 1 6, prepared by acting on glycerin with strong nitric acid, by which means three of the hydrogen atoms are removed and replaced by three molecules of nitric peroxide Its composition is $C_3H_5(NO_2)_3O_3$ Nitro-glycerin is a most powerful explosive agent, detonating when struck with a hammer, or when exposed to the detonation of fulminating mercury, &c When cautiously heated, it decomposes without explosion. Exposed to a low temperature, nitro-glycerin freezes to a crystalline mass; and a slight blow will sometimes cause the whole to explode with terrific violence.

NITRO-HYDROCHLORIC ACID. See *Nitric Acid*.

NITRO-MURIATIC ACID See *Nitric Acid*

NITRO-SUBSTITUTION COMPOUNDS See *Nitric Acid*

NOBILI'S FIGURES Nobili found that, if a drop of acetate of copper be placed on a silver plate, and if the point of a small rod, or wire of zinc be brought down upon the plate in the middle of the drop, the copper which is liberated attaches itself to the silver, forming rings around the point of the zinc, alternately light and dark To these are given the name of *Nobili's Rings or Figures* A similar effect may also be produced in the following way —Let finely-powdered litharge be boiled for some time in solution of caustic potash An alkaline solution of the lead oxide is thus obtained A silver plate is immersed in this liquid, and is connected with the positive electrode of a moderately powerful battery (8 or 10 cells of Bunsen) To the negative electrode is attached a platinum wire, which is passed through a glass tube, fused in and cut off, so that only the point is visible, and this is brought near to the silver plate. On doing so, binoxide of lead is deposited on the plate around the point in concentric rings, owing to a secondary action of the following nature —Some oxide of lead is decomposed, and the lead which is set free round the negative electrode, combines, with the oxygen set free at the positive electrode, to form binoxide, which attaches itself to the plate These rings are found in layers, whose thickness decreases from the middle, and they display therefore Newton's prismatic colours

NODE (*Nodus*, a knot) In astronomy, the points of intersection of any great circle on the celestial sphere with any other are called the nodes of the former circle on the latter The point at which the former circle passes from north to south of the latter is called the *ascending node*, its sign is ☊ The opposite node is called the descending node , its sign is ☋ The line joining the two nodes is called the nodal line

The ecliptic is usually the circle of reference, so that when the nodes of a planet are spoken of without further distinction, the nodes of that planet's orbit on the ecliptic are understood to be referred to

NODES AND SEGMENTS IN PIPES If the air in a tube, open at both ends, be set in vibration in such a way as to produce a musical note, when the fundamental note is sounded, the centre of the tube is alternately the region of maximum compression and maximum rarefaction , it is, in fact, a node or region of rest The two ends of the tube are the centres of ventral segments, and there the air is in the state of the most violent agitation The length of the pipe is half the length of the travelling wave If the pipe be closed at one end, and its fundamental note be sounded, the closed end of the pipe being at rest must be in contact with a node, the other and open end being as before the centre of a ventral segment It follows that the closed pipe will give a note an octave below an open one of the same length; or, in order that an open and a closed pipe may give the same notes, the closed one must be half as long as the open one (Compare *Organ Pipes*)

NODES AND SEGMENTS IN STRINGS A stretched string or wire, when gently plucked in the middle, will give rise to its fundamental note, accompanied by the feeble higher octave (See *Colour of Tone*) If a feather be placed on the centre of the string, and a point $\frac{1}{4}$ from one end be plucked, the string will vibrate in two segments, and possess three nodes, one at each end, and one in the middle If the feather be placed $\frac{1}{3}$ from one end, and the point $\frac{1}{6}$ from that end be plucked, the string will vibrate in three segments, and have four nodes, and so on. The higher octaves of the fundamental note are produced when the feather is placed (1) in the middle, (2) at $\frac{1}{4}$ the length, (3) at $\frac{1}{8}$ the length and so on If we examine such a string, we find that, when one segment is rising, the neighbouring two are falling, and *vice versa*, and that the points between the segments are nearly at rest If a stretched string when vibrating as a whole gives rise to a certain note, it will, when divided into n segments, give rise to n notes, the pitch of each of which is n times that of the original note There must evidently be in all cases $n+1$ nodes if there are n segments The formation of nodes can be well studied by hanging from the ceiling a long India-rubber tube filled with sand Such a tube, by agitating the free end, can be made to vibrate in a great variety of segments

NOMENCLATURE OF COLOURS There is no very accurate system of nomenclature of colours in general use The most accurate plan for scientific purposes is to refer to a portion of the solar spectrum by giving the distance between any two of the lines For compound colours not in the spectrum, such as pink or brown, definite portions of two spectra may be superposed For less accurate work, *Chevreul's Chromatic Circle* (which see) may be found useful In ordinary language, red, yellow, and blue are called primary colours. Combinations of these give secondary colours , red and yellow give orange , yellow and blue give green ; blue and red give purple Combinations of secondary colours give tertiary colours thus purple and orange give russet , orange and green give citrine , and green and purple give olive. Most colours, however, have some arbitrary name, such as Magenta, Phosphine, Hum-

boldt, or they are named after natural substances, thus Fuschine, emerald green, canary yellow, &c.

NON-CONDUCTOR OF ELECTRICITY A body which does not allow electricity to pass over its surface. Glass or vulcanite, for example, are non-conductors (See also *Conductor* and *Insulator*)

NON-ELECTRIC A term formerly used to designate a class of bodies which it was supposed could not be electrified by friction The metals, for example, came under this category But it is now well known that the reason why these bodies were apparently not electrifiable was, that in performing the experiment no precaution was taken to prevent the electricity from passing away from them as it was produced After the discovery of a difference between bodies as to the power of conducting electricity, it appeared at once that all those substances which had formerly been called "non-electrics" are conductors of electricity, and that by proper means they can be electrified as easily as those which were called *electrics* The distinction is therefore now broken down, though the terms are still to a certain extent in use

NORMA (The Square Rule) A southern cônstellation formed by Lacaille

NORMAL SOLAR SPECTRUM In the spectrum, as seen by prismatic dispersion, some parts are more expanded than others (See *Dispersion, Irrationality of*) A normal solar spectrum is one in which the fixed lines are mapped according to their wave-lengths, calculated from observations made with diffraction spectra (See A J Angstrom on the Normal Solar Spectrum Upsala, 1868 Also Roscoe's *Spectrum Analysis*, page 225)

NOVEMBER METEORS See *Meteors, Luminous*

NUBECULÆ (Little Clouds) Two very remarkable objects on the southern heavens, long known to sailors as the *Magellanic Clouds* They resemble in general appearance detached portions of the Milky Way, but on telescopic scrutiny are found to differ from the Milky Way in this, that whereas the galaxy shows few irresolvable nebulæ, the Nubeculæ exhibit great numbers of all orders of nebulæ This is especially the case with the Nubecula Major, within which Sir John Herschel counted no less than 278 nebulæ, besides noting 50 or 60 outliers He has pointed out that the existence of nebulæ of all orders, with stars from the 9th to lower orders, within a region which must be regarded as roughly spherical in form, should teach us to look with caution on the theory that nebulæ necessarily lie at inordinate distances beyond the fixed stars

NUCLEUS (A kernel) In astronomy the bright or condensed part of a comet

NUCLEUS When a bit of bread is thrown into a glass of champagne or of soda water, it immediately becomes covered with bubbles of gas which escape with effervescence, the bread being really effective as a nucleus in separating gas So also if a solid that has been exposed to the air, or handled, be put into the soda water or champagne, it will be immediately covered with gas If a similar solid be put into a liquid at or near the boiling point, it will produce a burst of steam or vapour, and so act for a time as a nucleus Milk, at a certain temperature, suddenly boils over from the presence of fatty nuclear particles suddenly liberating steam at every part of the liquid Again, if a similar body be put into a supersaturated saline solution, it will produce immediate crystallisation

It had long been observed that, under certain conditions, bodies become inactive, or cease to act as nuclei, as when a glass rod had been passed through flame, or boiled and dried out of contact with air It was supposed that the body thus treated had undergone a molecular change, or that the action of nuclei was catalytic (see *Catalysis*), or that the air exerted some mysterious influence, and so on Thus, it was supposed that a nucleus put into soda water or a boiling solution acted by carrying down air into which the gas or the steam could expand, and so escape

This subject has been investigated by Mr Tomlinson, who has greatly extended and multiplied the phenomena, and included them in a coherent theory, of which we propose to give some account Those who desire further information are referred to Mr Tomlinson's papers in the Phil Trans for 1868, p 659, to the Proceedings of the Royal Society, vols xvi 403, xvii 240, xviii 533 See also Phil Mag for Aug 1867 and the subsequent volumes, and the last 5 or 6 volumes of the Chemical News

Mr Tomlinson considers the contradictory action as to the behaviour of nuclei, noticed by former observers, to become clear by attending to this fact, namely, whether the solid nuclei were or were not chemically clean as to surface at the moment of contact with the solution in which they were placed.

A *nucleus* is defined as a body that has a different, generally a stronger, attraction for the gas, or the salt, or the vapour of a solution, than for the liquid which holds it in solution

A substance is *chemically clean* or *catharised* (see *Catharism*), whose *surface* is entirely free from any substance foreign to its own composition.

Reference is here made to surface only. A glass rod may be chemically clean, even though a particle of carbon or of ferric oxide be inclosed and shut off deep within it, but not so if the particle reach and form part of the surface itself So also a piece of wax or stearine may be full of dirty particles, but if a bit of the wax or stearine be melted into a globule, and so dropped into a supersaturated saline solution, it may not act as a nucleus, because the surface may consist of pure wax or stearine

Catharisation is the act of cleaning the surface of such alien matter, and the surface so cleaned is said to be *catharised*

As everything exposed to the air or the touch takes more or less a deposit or film of foreign matter, substances may be conveniently classed as *catharised* or *uncatharised*, according as they have been cleansed or not.

And it is not, perhaps, taking too much license with language to extend the term *catharised*, denoting, as it does, the condition of pure surface, to those substances whose surface has not required the process Thus, a flint stone in the rough has an uncatharised surface, but split it, and the inner surface of the pieces will for a time be clean

Referring to the definition of nucleus above given, substances, with reference to this definition, may be divided into *nuclear* substances and *non nuclear*

The nuclear are those that may *per se* become nuclei The non-nuclear are those that have not that quality

The nuclear substances would seem to be very few, the larger number of natural substances ranking under the other division

Under nuclear substances are those vapours and oily and other liquids that form thin films on the surfaces of liquids and solids, and, generally, all substances in the form of films, and only in that form. Thus, a stick of tallow, chemically clean, will not act, but a film of it will act powerfully

If a drop of a liquid be placed on the surface of another liquid, it will do one of three things (apart from chemical action)—(1) it will diffuse through the liquid, and in general, not act as a nucleus, or (2) it will spread out into a film, or (3) remain in a lenticular shape It becomes a film or a lens according to the general proposition, that if on the surface of the liquid A, whose surface tension is a, we deposit a drop of the liquid B, whose surface tension, b, is less than a, the drop will spread into a film, but if, on the contrary, b be greater than a, or only a little less, the drop will remain in the form of a lens Hence if B spread on A, A will not spread on the surface of B

This general proposition may not always apply in the case of supersaturated saline solutions, on account of the *superficial viscosity*, or the greater or less difficulty of the superficial molecules to be displaced

A glass rod drawn through the hand becomes covered with a thin film, or the same rod by exposure to the air contracts a film by the condensation of floating vapours, dust, &c, and in either case is brought into the nuclear condition

A second class of nuclear bodies are permanently *porous* substances, such as charcoal, coke, pumice, &c The action of these is chiefly confined to vapourous solutions, and if catharised having no power of separating salts from their supersaturated solutions

Under the non-nuclear, forming by far the larger class of substances, are glass, the metals, &c, while their surfaces are chemically clean

Among the non nuclear substances will be found air, for its ascribed nuclear character is due, not to itself, but to the nuclear particles of which it is the vehicle If air be filtered through cotton-wool it loses its apparent nuclear character, so also if heated

When a catharised body is placed in a supersaturated solution, such solution adheres to it as a whole, but if such body be non-catharised, the gas or vapour or salt of the solution adheres to it more strongly than the liquid portion, and hence there is a separation An active or non-catharised surface is one contaminated with a film of foreign matter, which filmy condition is necessary to that close adhesion which brings about the nuclear action, for it can be shown that an oil, for example, is non-nuclear in the form of a lens or globule, but powerfully nuclear in the form of a film

Some liquids (absolute alcohol, for example) form films, and act as nuclei by separating water instead of salt from supersaturated solutions

Other liquids (glycerin, for example) diffuse through the solutions without acting as nuclei.

Fatty oils may slowly saponify, or oil of bitter almonds form benzoic acid in contact with supersaturated solutions of Glauber's salt without acting as nuclei.

The solutions (say of Glauber's salt) are prepared with 1, 2, or 3 parts of the salt to 1 part of water, they are boiled, filtered into clean flasks, and covered with watch-glasses When cold, the watch-glass being lifted off, a drop of oil is deposited on the surface of the supersaturated

solution In an experiment described, a drop of pale seal oil formed a well-shaped film, with a display of iridescent rings, and immediately from the lower surface of the film there fell large flat prisms with dihedral summits of the 10 atom sodic sulphate. The prisms were an inch or an inch and a half in length, and three eighths of an inch across The crystallisation proceeded from every part of the lower surface of the film, and as one set of crystals fell off, another set was formed, until the whole solution became a mass of fine crystals in a small quantity of liquid, an effect quite different from the usual crystallisation which takes place when a supersaturated solution of Glauber's salt is subjected to the action of a nucleus at one or two points in its surface, as when motes of dust enter from the air, or the surface is touched with a nuclear point In such case small crystalline needles diverge from the point and proceed rapidly in well packed lines to the bottom, the whole being too crowded and too rapid to allow of the formation of regular crystals "

Similar experiments were made on solutions of Glauber's salt of different strengths, with drops of ether, absolute alcohol, naphtha, benzole, the oils of turpentine, cajuput, and other volatile oils, sperm, herring, olive, linseed, castor, and other fixed oils of animal and vegetable origin, with this general result, that whenever the liquid drop spread out into a film, it acted as a powerful nucleus, but when the oil formed a lens there was no separation of salt, even when the flasks were shaken so as to break up the lens into small globules If, however, a sudden jerk were given to the flask so as to flatten some of the globules against its sides into films, the whole solution instantly became solid A similar effect was produced by introducing a clean inactive solid for the purpose of flattening a portion of oil against the side of the flask

Stearine from sheep's tallow that had been exposed to the air produced immediate crystallisation, but by boiling the solution and covering the flasks, the stearine, now catharised, had lost its nuclear character on the cold solution Similar observations were made with the fixed oils that form lenses or globules in the solution So also volatile oils containing products of oxidation, dust, &c, are nuclear, but when catharised by being redistilled they are inactive in the globular state, active in the form of films

Supersaturated solutions of potash alum, ammonia alum, sodic acetate, and magnesia sulphate were also operated on with results similar to those obtained with solutions of Glauber's salt.

When a liquid forms a film on the surface of a supersaturated solution, the surface-tension of the solution is so far diminished as to bring the film into contact with the solution, when that differential kind of action takes place whereby the salt of the solution adhering more strongly to the film than the water of the solution, the action of separation and crystallisation, thus once begun, is propagated throughout A similar action takes place with solid bodies that have contracted filmy nuclei by being touched or drawn through the hand, or merely exposed to the air, they are active or nuclear by virtue of the films of matter which more or less cover them

On the other hand, when a drop of oil (or many drops) is placed on the surface of a supersaturated saline solution, and it assumes the lenticular form, or even flattens into a disc, such lens or disc is separated from actual contact with the solution by surface tension That the adhesion is very different from that of a film may be shown by pouring a quantity of recently distilled turpentine, for example, on the surface of chemically clean water, and scraping upon it some fragments of camphor, these will be immediately covered with a solution of camphor in the oil, which solution will form iridescent films, and sail about with the camphor, vigorously displacing the turpentine, and cutting it up into smaller discs and lenses So in the case of supersaturated saline solutions, the oil-lens is not sufficiently in contact with the surface of the solution to allow of the exertion of that differential kind of action whereby salt is separated Even when, by shaking, the oil is broken up into globules, and these are submerged, they are still so far separated from the solution by surface-tension as to prevent actual contact

It is remarkable that if care be taken to maintain the condition of chemical cleanliness, crystals do not act as nuclei to their own supersaturated solutions, because the solution adheres to them as a whole, and we have seen that in order for a nucleus to act it must adhere more strongly to the saline portion than to the aqueous portion of the solution, or *vice versâ*

So also if a highly supersaturated solution in a clean vessel, protected from the dust and motes of the air, be reduced in temperature from 0° F to —10°, the solution solidifies into an unstable hydrate, and in raising it to 32° it again liquefies without any regular crystallisation, such as takes place in the presence of a nucleus (See *Supersaturation*.)

NUTATION (*Nutatio*, a nodding) The name given to a small gyration of the earth's axis around the mean position due to precession. With reference to this mean position the motion of nutation takes place in about 19 years in a small ellipse, having a major axis of 18 5" and a minor axis of 13 74", but as the precessional motion is continually carrying the axis on-

wards in a much larger circle (see *Precession*), the actual motion is along a waved circular line The major axis of the small ellipse being towards the pole of the ecliptic, the effect of nutation so far as the obliquity of the ecliptic is concerned, is to cause it to oscillate 9 25″ on each side of its mean value, while as far as the position of the nodes of the earth's equator are concerned, nutation causes these nodes to be alternately in advance, or behind their mean place due to precession by 6 87″. For the cause of nutation see *Precession* Bradley discovered and explained the nutation of the earth's axis, not long after he had discovered the phenomenon called the aberration of the fixed stars

NUTRITION, ANIMAL AND VEGETABLE. See *Animal Nutrition*, *Vegetable Nutrition*

NUX VOMICA. See *Strychnine*

O

OBJECT GLASS The lens or combination of lenses which in a telescope or microscope forms the image of an object in its focus, which image is afterwards viewed by means of an eye-piece (See *Telescope*, *Microscope*)

OBLIQUITY OF THE ECLIPTIC The angle at which the earth's equator is inclined to the plane of the ecliptic (See *Ecliptic*) This angle is not constant, but within historic ages has been continually diminishing Astronomers recognised this change long before its cause was known It is now known to be part of an oscillatory process of change, taking place in a very long cycle and within somewhat narrow limits of change, the greatest variation on either side of the mean value of the obliquity being but 1° 21′ It must be remembered that this change is not due to a change in the inclination of the earth's equator to a fixed plane in the solar system, but is a real change in the position of the earth's path round the sun, and therefore in the position of the ecliptic upon the celestial sphere The following values suffice to indicate the nature of the change In A D 1100 the obliquity was 23° 48′ 43″, in the year 1870 it has a mean value of 23° 27′ 22 3″, in the year 1900 it will have a mean value of 23° 27′ 8 0″

OBSCURE HEAT The heat which is manifest beyond the red end of the spectrum, when a beam from the sun or other luminous source is decomposed by a prism, is thus called, also all heat which is unaccompanied by light—the heat, for instance, radiated from a vessel filled with boiling water The heat rays of the spectrum beyond the red are also known as *ultra red rays*, *dark heat rays*, *invisible heat rays* By separating the light rays proceeding from a luminous source from the heat rays (by filtering the beam through a solution of iodine in bisulphide of carbon), Tyndall found the following relationship between the luminous and obscure rays from different sources —

1 In the case of the most brilliant portion of a gas flame, if the total radiation, luminous and obscure, be divided into 25 equal parts, 24 parts consist of obscure rays and 1 of luminous rays

[illegible]e total radiation from a white hot platinum wire be divided into 24 parts, 23 parts consist of obscure rays and 1 of luminous rays

3 If the total radiation from the voltaic arc taken between carbon points, and produced by a battery of fifty cells of Grove's arrangement, be divided into 10 parts, 9 parts consist of obscure rays and 1 of luminous rays

The following table shows the results obtained by Tyndall with various sources, both obscure and luminous, by filtering through a solution of iodine in bisulphide of carbon, which entirely prevents the passage of luminous rays, while it allows the obscure heat rays to pass through it without absorption —

RADIATION FROM VARIOUS SOURCES THROUGH A SOLUTION OF IODINE IN BISULPHIDE OF CARBON

Source.	Proportion of Luminous rays Absorbed	Proportion of Obscure heat rays Transmitted.
Dark spiral,	0	100
Lampblack at 212° F.,	0	100
Red-hot spiral,	0	100
Hydrogen flame,	0	100
Oil flame,	3	97
Gas flame,	4	96
White hot spiral,	4·6	95·4
Electric light,	10	90

(See also *Calorescence*)

OBSERVATORY. A building intended for systematic observations of natural phenomena. (See *Observatory, Astronomical*, &c)

OBSERVATORY, ASTRONOMICAL The observation of celestial phenomena is now carried out in a systematic manner in nearly all civilised countries The buildings erected for this purpose have to be constructed with special reference to certain requisites They must not only be stable, but the principal instruments used for observing the stars must be free from all contact even with the firmly built walls of the observatory These instruments are therefore mounted on stone pillars sunk in the solid ground, and isolated from the floors of the rooms in which the observers work In addition to these precautions, it is found necessary to observe with extreme care changes which take place in the position of the support, owing to changes of temperature, humidity, and so on It would be wholly impossible, of course, to describe in such a work as this the various methods by which these and other requirements are secured, but it is necessary that the reader should thoroughly understand that those who work in our observatories are continually engaged in making such precautions more effectual, and are also continually on the watch to detect new forms of disturbance to which (in however slight a degree) their instruments may be exposed

The telescopes made use of in astronomical observatories are of two classes, *meridional* instruments, or those which can only be used to observe objects on the meridian, and *extra meridional* instruments, by which objects in other parts of the heavens can be observed To the former class belong the *transit instrument, transit circle,* and *mural circle*, to the latter the *equatorial instrument* and the *altitude and azimuth instrument* The subordinate instruments and appliances are too numerous for special mention (See Loomis' *Practical Astronomy*, and Pearson's *Introduction to Practical Astronomy*)

The principal public observatories at present in existence are those of Greenwich, Paris, Poulkova, and Cambridge, U S , but there are many others The number of private observatories is not only large, but continually increasing

OBSERVATORY, MAGNETIC The aim of magnetic observatories is to record the variations of the terrestrial magnetic elements—that is, of the magnetic declination, inclination, and intensity, for the purpose of deducing the laws according to which these variations take place The first regular and systematic observation was carried on at Gottingen by Gauss, and a band of private observers headed by him, but the establishment of the present national observatories is very much due to the influence of Humboldt He, in 1819, applied to the Russian Government, and obtained the institution of numerous magnetic establishments, and shortly after, with the aid of the Royal Society and the British Association, succeeded in inducing the British Government to take part in the work, and to set up observatories in Greenwich and Dublin, and in Toronto, Van Diemen's Land, at the Cape of Good Hope, and St Helena Systematic and synchronous observations were made and recorded, and from these have been deduced all that we know of the laws of the phenomena of terrestrial magnetism Some of the observatories originally established, having done their work, are, for the present at least, disused, but there are still some of them in constant employment, and new ones have lately been established at various places throughout the United Kingdom At present, observations are made at Greenwich and Dublin, at Kew, Glasgow, Armagh, and all the other chief meteorological establishments

We have described, under *Magnetism, Terrestrial*, and under the special designations, the instruments used in determining the various elements and the methods of doing so. We refer the reader to those articles, merely explaining here how photography is applied to obtain constant self-registration of the changes. To the magnets used in the various instruments are attached (as is described, see *Gauss's Magnetometer*) small light mirrors which turn with them Opposite to the mirror is placed a paraffin lamp, which lets fall through a small hole a beam upon the mirror The beam is reflected by the mirror, and sent through a narrow tube into a closed box wherein a cylinder is slowly turned by clock-work in front of the tube, and on the surface of the cylinder is a slip of photographically sensitized paper The spot of light falling upon the paper darkens it at the point where it falls, and a register is thus taken of the position of the spot, and hence of the deviation of the mirror and magnet from their normal position. Close to the moving mirror another small fixed mirror is supported, which also throws a spot of light through the tube on to the turning cylinder, and the position of this mirror is arranged so that, when the magnet stands at a certain position, which we may call zero, the beams of light from the two mirrors, the fixed one and that attached to the magnet, fall upon the same point of the cylinder Thus as the cylinder turns it will be seen that a zero line is traced out upon the paper by the spot from the fixed mirror, and it is from this zero line that measurements, upon which calculations are based, are made to the curve traced out by the other spot The paper of the cylinder is changed once in twenty-four hours, that on which the lines have been traced is photographically *fixed*.

Besides these self-registered records, from which the variations in the magnetic elements are deduced, observations are taken at regular intervals in order to determine the absolute values of them, and this, with the reduction and entry of the values obtained, constitutes the chief part of the magnetic work of an observatory. All the magnetic observatories are also meteorological observatories, and the state of the weather, temperature, barometric pressure, appearance of clouds, occurrence of auroras, electric perturbations at the various hours, are noted and carefully compared with the magnetic changes.

We refer our readers for more detailed information to the memoirs of Professor Lloyd in connection with the Dublin Observatory, to those of Sabine with respect to the foreign stations, and to the Reports of British Association on the subject of Kew Observatory, from 1842 onwards.

OBSERVATORY, METEOROLOGICAL. A building intended for the conduct of observations on the state of the atmosphere and weather changes generally. The principal instruments made use of in a meteorological observatory are the *barometer* for measuring the weight of the air, the *thermometer* for measuring its temperature, the *hygrometer* for measuring its moistness, the pluviometer or *rain-gauge* for estimating the hourly, daily, or monthly rainfall, the *anemometer* for measuring the force of the wind, and the *electrometer*. Lately a great advance has been made in the conduct of meteorological observations by the introduction of the practice of publishing frequent and early records of the state of the atmosphere or weather at different stations. By means of the telegraph it thus becomes possible to form a conception of the general state of the atmosphere over a country, or even a continent, in place of having mere isolated records of the phenomena presented at a single station.

OCCULTATION. (*Occultatio*, a concealment.) The concealment of one celestial body behind another. The term is commonly limited to the concealment of stars by the moon, and of Jupiter's satellites by the disc of their primary.

Occultations of stars by the moon afford important information respecting the lunar motions. They also supply an effective means of determining the moon's apparent diameter. The Astronomer-Royal has been led by examining the occultations of stars to the conclusion that irradiation considerably increases the moon's apparent diameter.

The present writer has pointed out a way in which occultations might be made to indicate the apparent diameters of the fixed stars.

OCEAN CURRENTS, INFLUENCE OF, ON CLIMATE. See *Climate*.

OCHRE. (ωχρα, pale yellow.) A name applied to several metallic oxides in a native pulverulent condition, when of a brownish yellow colour. It is, however, chiefly applied to hydrated peroxide of iron when fit for use as a pigment, and is called red ochre, yellow ochre, or brown ochre, according to colour. Cobalt ochre, bismuth ochre, chromo ochre, and antimony ochre are also terms occasionally used.

OCTANS. (The *Octant*.) One of Lacaille's southern constellations. The south pole of the heavens falls within this constellation, but no conspicuous star lies near enough to that pole to be called the southern pole star.

OCTAVE. (*Octo*, eight.) The interval or relationship of two musical notes, the numbers of vibrations of which in the same time are as 2 : 1. One note is an octave above or below another when the number of vibrations per second which produce the first is half or double of the number of vibrations producing the second. In the ordinary or diatonic musical scale the octave comprises eight notes, hence the name. (See *Musical Interval*.)

OCULAR SPECTRUM. When the eye has been steadily fixed for a short time on a bright coloured object, and is then suddenly turned away from it, an image of the object in the complementary colour will be observed to be temporarily impressed upon the retina. This image is called the ocular spectrum. (See *Accidental Colours*.)

OHMAD, or, OHM. (From Ohm, the propounder of the law known by his name.) A technical name for a certain amount of electric resistance. It is equal to the British Association unit of resistance. (See *Resistance, Units of*, and *Units, Electrical*.) Thus practical electricians talk of a piece of cable having 10 *Ohmads*, or more frequently 10 *Ohms*, of resistance, meaning thereby that its resistance is equal to that of 10 B. A. units, or British Association units.

OHM'S LAW. The numerical estimation of the value of any arrangement for the generation of an electric current is a matter of high practical importance, and the means of doing this is furnished by the celebrated Law of Ohm given in 1827. The problem is the following:— Given any number of electromotors, of specified kind and dimensions, such as a number of Bunsen's or of Daniell's cells, and any number of specified conductors, through which the electric current is sent, to find the strength* of the current, that is, the quantity of electricity which flows through any section of the circuit in a given time, and the law of Ohm states that *the*

* "Intensity" (*l'intensité*) it is called by French writers, and usually by translators of French books.

strength of the current is directly proportional to the whole electromotive force in operation, and inversely proportional to the sum of the resistances in the circuit. Ohm deduced this law from theoretical considerations; it is most strictly in accordance with experimental results, which demonstrates the justness of the hypothesis on which it is founded.

To make use of this law to best advantage, it is necessary to fix upon some consistent and convenient system of units by which the quantities mentioned above may be measured, and may be numerically expressed. This is done by the system drawn up by the committee appointed by the British Association to consider the standards of electrical resistance. An account of the units in which electrical measurements are made will be found under *Units, Electrical*. Let us consider the case of a single cell of a battery sending a current through a wire or other interpolar. Let S denote the strength of the current, E the electromotive force of the cell, and R the whole resistance. Ohm's law states that

$$S \propto \frac{E}{R}$$

or, if we choose our units aright,

$$S = \frac{E}{R}$$

The electromotive force depends upon the nature of the materials used in the battery cell. Thus the electromotive force of a cell of Bunsen differs from that of a cell of Daniell. The nature of the cell then remaining the same, if we diminish the resistance we increase the current, or if we increase the resistance we diminish the current. Now the resistance, as Ohm first clearly pointed out, consists of two parts, that within the cell or other electromotor, and that without. Let l stand for the resistance of the liquid within the cell, and w for the resistance of the wire or other interpolar; then

$$R = l + w \text{ and } S = \frac{E}{l + w}$$

Let us now consider the case when several electromotors are used in conjunction to pass a current through a given interpolar resistance w, and, to simplify the matter, we shall assume what is generally the case that a number of cells of the same kind are made use of, and we shall call the electromotive force of each cell E, and the internal resistance of each l, as before. According to Ohm's law the strength of the current is proportional to the sum of all the electromotive forces divided by the sum of all the resistances; hence, if n be the number of cells used,

$$S = \frac{nE}{nl + w}$$

If the interpolar resistance w is very small compared with l the internal resistance of the cell, which would be the case if the electrodes of the battery or cell are connected by a short thick copper wire, it may be neglected, and we get

$$S = \frac{nE}{nl} = \frac{E}{l}$$

an expression the same as that for a single cell; and we see the reason of the fact that the current in such a case is not increased by joining a number of cells in series, that is, the platinum of the first to the zinc of the second, and so on. In fact, the electromotive force does almost all its work in sending the current through the circuit against the internal resistance of the cells, and though the electromotive force is increased by increasing the number of cells, the resistance is also increased in the same proportion, and the strength of the current remains the same. On the other hand, when the battery is used to send a current through a very great interpolar resistance, as is the case with a long telegraph line, the internal resistance of the cells may be neglected in comparison with the external resistance. For a battery of n cells, then we have

$$S = \frac{nE}{w}$$

which shows that the strength of the current, as long as that is the case, increases directly with the number of cells used.

Again, suppose we alter the cells by making the plates larger, or, what is the same thing, suppose we associate a number of cells, so that all their zincs are joined together, and likewise all the platinums. In this case we do not obtain a system whose electromotive force is greater than that of a single cell, but by increasing the size of the plates we increase the section of the

cell, and thus diminish the resistance, which is inversely proportional to the section of the conductor The same is the case when we join a number of cells as we have described them. Let m be the number of cells used, then

$$S = \frac{E}{\frac{l}{m} + w} = \frac{mE}{l + mw}$$

Thus, if w is small compared with l, we increase the current by employing a large number of cells Yet we do not obtain an unlimited increase in the strength of the current, for ultimately mw in the denominator becomes great compared with E, and the fraction becomes

$$S = \frac{mE}{mw} = \frac{E}{w}$$

Lastly, Ohm's law shows us how, given a certain number of cells and a certain external resistance, to arrange our battery so as to produce the greatest current With a number of cells we may make a number of different combinations, each of which would give a different strength of current when applied to a fixed interpolar resistance Thus we might arrange them all in a series, and this would be best, as we have seen, when the interpolar resistance is very great, or we might couple the zinc to zinc and platinum to platinum, which would be best with an extremely small interpolar resistance, or we might couple sets of the zinc to zinc and platinum to platinum and arrange these sets in series Suppose we have n cells, and that we divide them into t sets having s cells in each, so that $n = t\,s$, then, according to the principle we have laid down, the equation

$$S = \frac{t\,E}{t\frac{l}{s} + w} = \frac{nE}{t\,l + sw}$$

expresses the strength of the current in terms of the electromotive force E and the resistance l that of a single cell, and w that of the interpolar conductors It is easy to prove from this that S is a maximum, that is to say, that the greatest current is obtained when

$$\frac{t\,l}{s} = w$$

that is, when the whole internal resistance is equal to the external resistance. For example, give 27 cells each with an internal resistance expressed by the number 12, it is required to arrange them most advantageously to send a current through a interpolar resistance expressed by the number 36 If we arrange them in systems of 3 each and make the 9 systems to act in series, we shall have

$$\frac{t\,l}{s} = \frac{9 \times 12}{3} = 36 \quad \text{in which case } S = \frac{E \times 27}{9 \times 12 + 3 \times 36} = \frac{E}{8}$$

It will be found on making the calculation that this is the greatest current that can be obtained under the conditions given

OIL. A general term applied to an immense number of bodies which have certain physical properties in common. They may be divided into two great classes, fixed oils and volatile or essential oils Oils are almost all liquid at the ordinary temperature, are more or less viscid, and insoluble in water They are inflammable either at the ordinary temperature or when heated The fixed oils are not volatile without decomposition Some of them oxidise when exposed to the air and dry to a caoutchouc-like substance, whilst others are non-drying The essential oils are of a peculiar pungent odour, distil without decomposition, and are very inflammable. The following table gives the most important oils .—

FIXED OILS.

Drying	Non-drying.	Non-drying
Linseed oil.	Almond oil	Earth nut oil
Poppy oil.	Beech nut oil.	Oil of mustard.
Sunflower oil.	Castor oil	Rape seed oil.
Walnut oil.	Cotton seed oil.	Sesame oil.
Tobacco seed oil.	Colza oil.	Olive oil.
Cress seed oil.		

ESSENTIAL OILS.

Oil of anise	Oil of cloves	Oil of nutmeg
Oil of bergamot.	Oil of lavender.	Oil of orange peel.
Cajeput oil	Oil of lemon.	Oil of peppermint
Oil of carraway.	Oil of mint.	Oil of rose
Oil of cassia.	Oil of myrrh.	Oil of thyme
Oil of cedar.	Oil of neroli.	Oil of turpentine.

OIL OF BITTER ALMONDS See *Almonds, Oil of Bitter.*
OIL OF TURPENTINE See *Turpentine, Oil of.*
OIL OF VITRIOL See *Sulphur, Sulphuric Acid*

OLEFIANT GAS Known also as *ethylene, bi carburetted hydrogen*, and *heavy carburetted hydrogen* Is a colourless gas, odourless, and irrespirable Specific gravity 0 9784. Formula C_2H_4 It is insoluble in water, sparingly soluble in alcohol, freely so in ether In chemical properties it acts as as a diatomic radical, uniting with chlorine, bromine, oxygen, sulphur, &c, and forming ethers with the peroxides of various acid radicals With the elements of two atoms of peroxide of hydrogen it forms the diatomic alcohol glycol (See *Alcohols, Series of*)

OLEIC ACID A fatty acid of the composition $C_{18}H_{34}O_2$, contained in tallow, olive, and other oils, above 14° C (57° F) it is liquid, below that, it is a white crystalline solid It forms salts with bases, the oleate of sodium enters into the composition of soap

OPACITY (*Opacitas*) That quality of a substance which causes it to be impervious to light The term is sometimes extended to the whole spectrum, thus we speak of alum as being opaque to heat, and orange glass as being opaque to the actinic rays. Opacity is the opposite to transparency

OPACITY OF TRANSPARENT MEDIA In the passage from one medium to another of a different refractive index light is always reflected, and this reflection may be so often repeated as to render a mixture of two transparent substances practically impervious to light The frequency of the reflections at the limiting surfaces of air and water renders *foam* opaque, whilst the blackest clouds owe their gloom to this repeated reflection which diminishes their transmitted light

OPALESCENCE OF THE ATMOSPHERE Professor Roscoe has carried out an elaborate investigation on the opalescence of the atmosphere, and has thrown light upon the vexed question of the cause of the blue colour of the heavens, and the ruddy tints of sunrise and sun set (*Proceedings of the Royal Institution*, June 1, 1866) Since the time of Leonardo da Vinci, this subject has been a favourite ground for the display of meteorological speculations Da Vinci, and, afterwards, Goethe, believed that the blueness of an unclouded sky was due to the passage of the white light through the atmosphere containing finely divided particles Newton explained the blue colour of the heavens by the existence in the atmosphere of very minute hollow vesicles of water upon which, as on a soap bubble, the colours of thin plates become perceptible, and according as the thickness of the walls of these vesicles increased so would the colour change from blue to yellow, orange and red, and thus by very frequent reflections the various tints from sky-blue to sunset red could be explained Founded upon this theory Clausius has calculated the relative intensities of direct sunlight, and the diffuse reflected light of the sky for varying altitudes of the sun Some physicists have assumed that the air itself has a blue colour, whilst others have admitted that if air be of a blue colour by *reflected* light, it should appear red by *transmitted* light Others again, in order to avoid the difficulty of explaining the great variety of sunset tints, have assumed these tints to be an ocular deception, caused by the presence of clouds which receive and repeat the colour Many physicists have suggested that the atmosphere being filled with small particles of floating solid matter acts like an opalescent medium, and transmits only red light, but it is to Brücke (*Pogg Ann*, vol lxxxviii, p 363), that we are indebted for a complete statement and masterly investigation of this view of the subject Forbes again ("*On the Colour of Steam under certain circumstances, and on the Colours of the Atmosphere*," *Edin Trans* xiv, p 371, *Phil Mag* xiv xv 3d ser) explains the phenomena in an entirely different manner, for he, having observed that under certain circumstances aqueous vapour, or rather water in finely divided particles, is able to absorb the blue rays, and that the sun looked red when seen through a particular portion of a jet of escaping steam, attributes the sunset red solely to the presence of water in this peculiar state of division Dr Roscoe (*Phil Trans* 1865, p 605), has explained the principles of a method by the application of which we are able to gain some knowledge of the distribution of the chemically active rays on the earth's surface and their variation from time to time (see *Actinometer, Daylight, Actinic Intensity of*). By comparing the mean intensities for the summer

and winter solstices, and the equinoxes, as measured at Manchester, it has been shown that the increase of chemical action from December to March is not nearly so great as that from March to June This difference cannot be attributed to the common absorption exerted by the atmosphere, but may be explained as being the necessary consequence of a peculiar absorptive action which the atmosphere effects upon the chemically active rays, and to which the name of opalescence may be given The method adopted by Dr Roscoe consists simply in determining the chemical intensity of the total daylight (sunlight and diffused light), and immediately afterwards shading off the sun's direct rays by means of a small disc or sphere of metal whose apparent diameter is only slightly greater than that of the solar disc, seen from the position of the sensitive paper In this way the chemical intensity of the total (direct and diffused) light is compared with that given off by the whole of the heavens alone, and the difference gives the chemical intensity of the direct sunlight Experiment soon proved that the relative intensity of the actinic light coming directly from the sun is very much less than would be ordinarily supposed, judging from the intensity of the visible light, thus at Manchester it was found when the sun was 12° 3′ above the horizon, that of 100 actinic rays falling on the horizontal surface less than 5 were due to the direct sunlight, whilst 95 came from the diffused light of the heavens, even when the sky was unclouded, at the same instant, of 100 rays of visible light as affecting the eye, 60 came directly from the sun, and only 40 from the diffused skylight The explanation of this anomalous result is thus given by Dr Roscoe Let us take a very slightly milky liquid, such as water containing $\frac{1}{10}$th grain of suspended sulphur in the gallon So slight is the opalescence thus produced that we can scarcely detect it, nevertheless this minute trace of very finely divided sulphur is sufficient to cut off the chemically active rays We have here an exact imitation of the condition of the atmosphere as regards the actinic rays We see that light of a high degree of refrangibility cannot pass through the water containing the finely divided sulphur, because it is reflected back again by the particles of sulphur If the white beam of the electric lamp be passed through a tube 3 feet long fitted with glass plates at each end and filled with a scarcely visibly opalescent liquid, all the blue, green, and yellow rays will be completely cut off and the emerging beam of light is deep red If the visible light is diminished to one third, by means of opalescent sulphur the chemically active rays are all together cut off In opal glass we have perhaps a still better illustration of the action of minute particles on rays of light The opalescence of the glass is caused by the presence of very minute particles of phosphate of lime or of arsenious acid which are disseminated throughout the mass By reflected light this glass appears white, or bluish white, by transmitted light it appears orange If we place a bright source of white light behind the glass we see that the direct rays are red, whilst the general diffused light reflected from the particles of the finely divided matter in the glass is bluish white So, too, the atmosphere is filled with particles which reflect the blue rays and transmit the red What the exact nature of these particles may be, it is hard to say We know, however, that the air is always filled with minute solid bodies, as is evidenced by the germs which are constantly present and cause fermentation and putrefactive decomposition We see it also in the fact that soda can always be detected in the atmosphere by spectrum analysis We notice these particles as motes dancing in the sunbeam, or in those grander paths of light which sometimes shoot up into the sky from a setting sun The phenomenon may, perhaps, be caused by that finely divided extra terrestrial meteoric dust which is, according to many physicists, constantly falling through the atmosphere to the earth's surface These solid particles in the air *may* produce the above effects, and certainly could produce them, but we must remember that small particles of water are also able to transmit only red rays, and that, as Forbes has shown, the glorious ruddy tints of the setting sun are doubtless partly caused by aqueous vapour The following tables give the results of observations by Dr Wolkoffat, Heidelberg, by Mr Baker at Kew, by Mr Baxendell at Cheetham Hill, by Dr Roscoe at Owen's College, and by Mr Thorpe, at Para —

HEIDELBERG

	Number of Observations	Range of Altitude of Sun	Mean Altitude of Sun	Intensity of Sky or diffused Daylight	Intensity of direct Sunlight	Ratio of Sun to Sky
Group 1	10	0° to 15°	7° 15′	048	002	0 041
„ 2	19	15 30	24 43	134	066	0 472
„ 3	31	30 45	34 34	170	136	0 800
„ 4	22	45 60	53 37	174	263	1 511
„ 5	17	above 60	62 30	199	319	1 603

CHETHAM HILL.

	Number of Observations		Mean Altitude of Sun	Intensity of Sky or diffused Daylight.	Intensity of direct Sunlight.	Ratio of Sun to Sky
	Sky.	Sun.				
Group 1	23	24	19°30′	064	012	0 187
„ 2.	22	22	25 31	091	·019	0 208
„ 3.	18	17	34 8	104	026	0 250

OWEN'S COLLEGE.

	Number of Observations		Mean Altitude of Sun	Intensity of Sky or diffused Daylight.	Intensity of direct Sunlight.	Ratio of Sun to Sky
	Sky.	Sun.				
Group 1	33	34	17° 8′	066	007	0 106
„ 2	20	24	26 38	074	008	0 108
„ 3.	4	5	54 12	140	043	0 308

KEW.

	Number of Observations		Mean Altitude of Sun	Intensity of Sky or diffused Daylight	Intensity of direct Sunlight.	Ratio of Sun to Sky
	Sky	Sun.				
Group 1	18	18	12°55′	0 065	0 014	0 213
„ 2.	8	8	21 8	0 072	0 030	0 416
„ 3.	7	7	28 16	0 104	0 056	0 538
„ 4	6	6	41 23	0 135	0 107	0 792

PARA.

	Number of Observations		Mean Altitude of Sun	Intensity of Sky or diffused Daylight	Intensity of direct Sunlight.	Ratio of Sun to Sky
	Sky.	Sun.				
Group 1.	20	20	42°21′	451	168	372
„ 2.	25	25	62 49	552	277	501
„ 3.	25	25	77 20	·660	·267	404

OPALS, OPTICAL PHENOMENA OF These have been examined by Mr. Stokes (*Proceedings of the Royal Society*, 1869, p 448) When a good fiery opal is examined in day, sun, or artificial, light, it appears to emit vivid flashes of crimson, green, or blue light, according to the angle at which the incident light falls, and the relative position of the opal and the observer; for the direction of the path of the emitted beam bears no uniform relation to the angle of the incident light. Examined more closely, the flashes of light are seen to proceed from planes or surfaces of irregular dimensions inside the stone, at different depths from the surface, and at all angles to each other. Occasionally a plane, emitting light of one colour, overlaps a plane emitting light of another colour, the two colours becoming alternately visible upon slight variations of the angle of the stone, and sometimes a plane will be observed which emits crimson light at one end, changing to orange, yellow, green, &c., until the other end of the plane shines with a blue light, the whole forming a wonderfully beautiful solar spectrum in miniature. The colours are not due to the presence of any pigment, but are interference colours caused by minute striæ or fissures lying in different planes By t[illegible] round, and observing it from different directions, it is generally possible to get a position in which it shows no colour whatever. Viewed by transmitted light, opals appear more or less deficient in

transparency, and have a slight greenish-yellow or reddish tinge If an opal, which emits a fine broad crimson light, is held in front of the slit of a spectroscope or spectrum-microscope at the proper angle, the light is generally seen to be purely homogeneous, and all the spectrum that is visible is a brilliant luminous line or band, varying somewhat in width, and more or less irregular in outline, but very sharp, and shining brightly on a perfectly black ground If now the source of light is moved, so as to shine into the spectrum apparatus through the opal, the above appearance is reversed, and we have a luminous spectrum with a jet black band in the red, identical in position, form of outline, and sharpness with the luminous band previously observed. If instead of moving the first source of light (which gave the reflected luminous line in the red), another source of light be used for obtaining the spectrum, the two appearances of a coloured line on a black ground, and a black line on a coloured ground, may be obtained simultaneously, and they will be seen to fit accurately Those parts of the opal which emit red light are therefore seen to be opaque to light of the same refrangibility as that which they emit, and upon examining, in the same manner, other opals which shine with green, yellow, or blue light, the same appearances are observed, showing that this rule holds good in these cases also It is doubtless a general law, following of necessity the mode of production of the flashes of colour

OPAQUE BODIES, INDICES OF REFRACTION OF As the index of refraction is the tangent of the angle of polarisation (see *Polarising Angle*), if the polarising angle is known, the index of refraction can be calculated In this manner it is possible to ascertain the indices of refraction of many opaque bodies, such as metals, provided the maximum polarising angle of the body is known Under the heading *Metallic Reflection*, the polarising angle of several such bodies is given, and from these data the following table may be calculated.—

Name of Substance	Index of Refraction	Name of Substance	Index of Refraction.
Grain tin,	4 915	Steel,	3 732
Mercury,	4 893	Bismuth,	3 689
Galena,	4 773	Pure silver,	3 271
Iron pyrites,	4 511	Zinc,	3 172
Gray cobalt,	4 309	Tin plate, hammered,	2 879
Speculum metal,	4 011	Jewellers' gold,	2 864
Antimony, melted	3 844		

OPERA-GLASS An opera-glass is a short achromatic telescope, arranged so as to give a low magnifying power (two or three diameters at most), together with as large a field and as much light as possible The object-glass is of the ordinary achromatic construction, but the eye-piece consists of a concave achromatic lens placed within the focus This prevents the inversion of objects An opera-glass usually consists of two barrels side by side, one for each eye, provided with rackwork adjustment The telescope first used by Galileo was of this construction (See *Galilean Telescope*)

OPHIUCHUS (ὄφις, a serpent, and ἔχω, to hold The serpent-holder) One of Ptolemy's northern constellations, sometimes called Serpentarius It is represented under the figure of a man grasping a serpent This constellation is of great extent, and contains many remarkable double stars and other telescopic objects The star 70 Ophiuchi is a well known binary

OPHTHALMOSCOPE (οφθαλμος, the eye, and σκοπεω, to view) An instrument for viewing the interior of the eye Light is condensed into the eye by means of a concave mirror, through a small hole in the centre of which the observer examines the eye by means of a lens This is the simplest form, but ophthalmoscopes are now made much more complicated, their efficiency being increased by numerous adjustments

OPIUM The dried juice of the capsules of the white poppy (*papaver somniferum*) It is a somewhat hard, brown, resinous mass, of a peculiar taste and odour It is a very complex substance, of the highest medicinal value, and contains several alkaloids, the most important of which are *morphine* and *narcotine*, which see

OPTIC AXES OF CRYSTALS Crystals which possess the property of double refraction (see *Double Refraction of Crystals*) exert it in different degrees, according to the direction in which the ray of light passes through them The direction along which there is no double refraction of the light is called the optic axis of the crystal. Crystals belonging to the pyramidal and rhombohedral systems have only one optic axis, and are therefore called *uniaxial.* Crystals belonging to the prismatic, oblique, and anorthic systems, have two optic axes, and are called *biaxial.* The axes in biaxial crystals may be at any inclination to one another, from a few degrees to 90°. The relative position of the axes is altered by temperature, and sometimes varies according to the coloured light by which they are examined

The following table of the more important biaxial crystals gives the inclinations of their optic axes to each other. (See Brooke's *Natural Philosophy*, p. 686).

Principal Axis, Positive.		Principal Axis, Negative.	
Sulphate of Nickel,	3° to 42°	Nitrate of potash,	5°20′
Biborate of soda,	28°42′	Carbonate of strontia,	6°56′
Sulphate of baryta,	37°42′	Talc,	7°24′
Heulandite,	41°40′	Carbonate of lead,	10°35′
Sodio sulphate of magnesia	46°49′	Mica, some varieties,	14°0′
Brazilian topaz,	49° to 50°	Sulphate of magnesia,	37°24′
Sulphate of strontia,	50°0′	Carbonate of ammonia,	43°24′
Sulphate of lime,	60°0′	Sulphate of zinc,	44°28′
Nitrate of silver,	62°16′	Sugar,	50°0′
Scottish topaz,	65°0′	Phosphate of soda,	55°20′
Sulphate of potash,	67°0′	Tartrate of potash,	71°20′
Potassio tartrate of soda,	80°0′	Tartaric acid,	79°0′

OPTICAL PHENOMENA OF OPALS See *Opals, Optical Phenomena of.*
OPTICAL SACCHAROMETER. See *Saccharometer, Optical*

OPTICS (*οπτικος*, *οπ*, root of *οπσομαι*, future of *ὁραω*, to see) The science which treats of the phenomena of light with respect to vision

ORBIT (*Orbita*, a wheel track) In astronomy, the path followed by any celestial body (See *Planets*, *Stars*, *Double*, *Lunar Theory*, *Keplerian System*, &c

ORCEINE An uncrystallisable colouring matter contained in commercial archil It is prepared from orcin by the action of ammonia and atmospheric oxygen It is slightly soluble in water and very soluble in alcohol, forming a deep scarlet solution. Formula $C_7H_7NO_3$ It is sometimes known as lichen-red

ORDINARY AND EXTRAORDINARY RAY OF LIGHT When a ray of common light passes through a rhombohedron of calcspar, it is divided into two oppositely polarised rays, the one which is refracted in accordance with the general law for transparent media, is called the ordinary ray, whilst that which is refracted so as to form a greater angle with the axis than the ordinary ray is called the extraordinary ray

ORE (Danish, *aare*, a vein) Natural compounds of metals with the non-metallic elements, chiefly oxygen or sulphur, are called ores of the metals When the metals occur by themselves, or alloyed with other metals, they are said to be native Sometimes the mineral in which the metal or other valuable substance is found is called the ore, thus we hear of diamond ore, sulphur ore, &c In such cases, the term matrix would be more appropriate Iron pyrites (native sulphide of iron), which is so largely used as a source of sulphur, is now called sulphur ore

ORGAN (*ὀργανον*, an instrument) In music a collection of wind instruments so attached to a key-board that they may be played by the fingers of a single performer The organ was invented at an early period, and is attributed to Ctesibius, a barber of Alexandria Vitruvius mentions an organ which was blown by the fall of water, St Jerome describes one with twelve pair of bellows, which could be heard at a distance of a thousand paces, and of another at Jerusalem, which could be heard on the Mount of Olives

Large organs consist of several rows of pipes, with the same series of notes in each When a key is pressed down by the finger, a valve opens and allows air from the bellows to pass through an aperture in the sound-board into a passage communicating with the pipes in each row of the same pitch By means of stops usually placed at the side of the organ key board, and attached to registers or slides in this passage, as many of these rows as are required may be opened so as to play when the air is driven into the passage By pushing in the stops, the corresponding rows are closed Organ pipes either have a vibrating metallic tongue, or simply an aperture with a cross lip to cut the air and set it in vibration The former are termed reed pipes, and the latter flute pipes. The pitch of a reed pipe depends on the length and thickness of the tongue, the shape and length of the pipe giving the quality to the note, while the pitch of a flute pipe depends on its length only The pipes are usually made either of wood or of pewter, *i e*, lead mixed with a small proportion of tin. The wooden pipes are usually square, and the metallic ones cylindrical The usual compass of a large organ is 4½ octaves played from the key-board, and 2½ octaves in the pedal-organ played by the feet. A swell organ is one which is inclosed in a box with shutters, which may be opened or closed so as to give a swelling effect to the sound

ORGAN PIPES The "Pandean Pipes" form an instrument which illustrates the simplest form of the wind organ If a tube closed at one end be held with its closed end downwards, and its open end pressed against the under lip, and if air be forced across the open end, a note can be produced which is shriller the shorter the tube. The Pandean Pipes are a series

of such tubes bound together, along the open ends of which the mouth is passed, the tubes vary in length and diameter, and are of such dimensions that the notes produced form a gamut or musical scale In the organ pipe the air is forced into a sort of box or mouthpiece, and escapes therefrom into the air through a narrow slit at the top of the box The pipe fits on to the end of this box. The side of the pipe near the slit is depressed inwards, and slightly cut away, so that the sharp edge of the depressed portion is just above the slit in the mouthpiece When air is forced into the mouthpiece, the current is split upon the sharp edge of the pipe; and as it escapes into the air, it causes waves to be established in the pipe The number of vibrations produced per second depends upon (1) the length of the pipe, (2) whether it is closed or open at the end, (3) upon its depth, that is, the distance from the front to the back, supposing the slit to be in the front The width of the pipe is without effect upon the pitch of the note, but affects the loudness If we suppose the pipe to give its fundamental note, the length of the pipe, if closed at the end, must be ¼ of the wave-length of the note. (See *Wave-length.*) In an open organ pipe the length of the pipe is ½ the wave-length. By diminishing the size of the slit, or increasing the rapidity of the air current, the harmonics of these notes can be formed It follows that if two organ pipes, otherwise alike and treated alike, give the same note—one being closed and the other open—the open pipe is twice as long as the closed one In order to ascertain experimentally the condition of the air as to the position of its loops and nodes, that is, points of rest and regions of greatest amplitude when the pipe is sounding its fundamental note or its harmonics, a little tambourine of thin stiff paper may be raised and depressed as the pipe is sounded Thus, in a closed pipe, the agitation is found to be greatest at the mouthpiece, and to diminish gradually to the closed end where there is a node In an open pipe the end of the tube, the mouthpiece and the centre, are found to be loops or regions of greatest amplitude of vibration, while two nodes are found at the distance of ¼ and ¾ from the mouthpiece.

ORGANIC FAMILIES, SERIES OF. According to Dr. Odling —

	Monatomic Alcohols.	Monatomic Acids	Diatomic Acids
Fatty	$C\,H_4\,O$ Methylic	$C\,H_2\,O_2$ Formic.	—
	C_2H_6O Ethylic	$C_2H_4O_2$ Acetic.	$C_2H_2O_4$ Oxalic.
	C_3H_8O Propylic.	$C_3H_6O_2$ Propionic.	$C_3H_4O_4$ Malonic
	$C_4H_{10}O$ Butylic	$C_4H_8O_2$ Butyric.	$C_4H_6O_4$ Succinic
	$C_5H_{12}O$ Amylic.	$C_5H_{10}O_2$ Valeric.	$C_5H_8O_4$ Pyrotartric.
	$C_6H_{14}O$ Hexylic.	$C_6H_{12}O_2$ Caproic.	$C_6H_{10}O_4$ Adipic
	$C_7H_{16}O$ Anthylic.	$C_7H_{14}O_2$ Œnanthic.	$C_7H_{12}O_4$ Pimelic
	$C_8A_{18}O$ Octylic	$C_8H_{16}O_2$ Thetic.	$C_8H_{14}O_4$ Suberic
	$C_9H_{20}O$ Nonylic.	$C_9H_{18}O_2$ Pelargic.	$C_9H_{16}O_4$ Anchoic.
	—	$C_{10}H_{20}O_2$ Rutic	$C_{10}H_{18}O_4$ Sebacic.
	—	$C_{11}H_{22}O_2$ Euodic.	
	$C_{12}H_{26}O$ Laurylic.	$C_{12}H_{24}O_2$ Lauric.	
	—	$C_{13}H_{26}O_2$ Cocinic.	
	—	$C_{14}H_{28}O_2$ Myristic.	
	—	$C_{15}H_{30}O_2$ Benic	
	$C_{16}H_{34}O$ Cetylic.	$C_{16}H_{32}O_2$ Palmitic.	
	—	$C_{17}H_{34}O_2$ Margaric.	
	—	$C_{18}H_{36}O_2$ Stearic	
	—	$C_{19}H_{38}O_2$ Balenic.	
	—	$C_{20}H_{40}O_2$ Arachidic.	
	—	$C_{21}H_{42}O_2$ Nardic.	
	$C_{27}H_{56}O$ Cerylic.	$C_{27}H_{54}O_2$ Cerotic	
	$C_{30}H_{62}O$ Melylic.	$C_{30}H_{60}O_2$ Melissic.	
Aromatic.	C_6H_6O Anilic.	$C_6H_4O_2$ Collic	—
	C_7H_8O Benzylic.	$C_7H_6O_2$ Benzoic.	—
	$C_8H_{10}O$ Xylylic.	$C_8H_8O_2$ Toluic	$C_8H_6O_4$ Phthalic.
	$C_9H_{12}O$ Retylic.	$C_9H_{10}O_2$ Deltic	$C_9H_8O_4$ Insolinic. (?)
	$C_{10}H_{14}O$ Cymylic.	$C_{10}H_{12}O_2$ Cuminic.	—

ORIENTAL AMETHYST. See *Aluminium.*

ORIENTAL TOPAZ See *Aluminium.*

ORION One of Ptolemy's constellations. The celestial equator divides this constellation into two nearly equal portions It is, beyond question, the finest asterism in the heavens. Independently of the bright orbs which render it an object of admiration to all, it is distinguished among telescopists for the surprising number of objects of interest which it presents to

their observation. Its two leading orbs, Betelgeux and Rigel, are each remarkable, the former as one of the most perplexing variables in the heavens (see *Stars, Variable*), the latter as a fine double. The central star of the belt (Epsilon) is involved in nebulosity, and recognised as a variable. The lowest star of the sword (Iota) is also involved in nebulosity But more interesting than either of these objects, or than any of the double, triple, and multiple stars with which the constellation abounds, is the wonderful nebula which surrounds the middle star (Theta) of the sword This amazing nebula has, perhaps, attracted more attention among telescopists than any other object in the heavens (See *Nebulæ.*)

ORPIMENT. See *Arsenic, Sulphides of.*

ORRERY A machine for showing the motions of the planets, satellites, &c As Sir John Herschel has well remarked, orreries are "very childish toys"

OSCILLATION, CENTRE OF (*Oscillatio*, from *oscillum*, a swing.) A point in a pendulum such that, if all the weight of the pendulum were concentrated at the point, and the latter rigidly connected with the centre of suspension of the pendulum, the oscillations would be performed in the same time as before It is the distance of the centre of oscillation from the centre of suspension which has to be considered as the length of the pendulum in all mathematical calculations (See *Pendulum*)

OSCILLATIONS, COEXISTENCE OF SMALL The motion of any system of bodies may always be supposed to be made up of a number of simultaneous oscillations analogous to those of a simple pendulum, each of which is called a simple oscillation We can determine the motion of the system from general laws if we know the conditions under which it exists at some particular instant of time The entire motion of a body is made up of all the simple oscillations of which its particles are capable under the existing conditions When the periods of the simple oscillations are commensurable, the whole system will return to the same state in an interval of time equal to the least common multiple of these periods. (See Lagrange's *Mécanique Analytique*)

OSMIRIDIUM See *Iridosmium*

OSMIUM (ὀσμή, odour) An element associated with platinum, usually considered to be a metal, but possessing properties which have led many persons to consider it a metalloid Symbol, Os, atomic weight, 199, specific gravity, 21 4 It usually occurs alloyed with iridium, in the form of metallic looking white grains, called *osmiridium* or *iridosmine* It is the most infusible of all metals, as it does not melt at the temperature at which platinum is a gas In the densest state in which it has been obtained it is a bluish white, rather spongy, metallic mass, which will scratch glass In the pulverulent state it is very combustible, forming osmic acid The same oxide is also formed when the compact metal is heated in the air to redness The only compound which we need mention is the tetroxide, known as

Osmic Acid (OsO_4) This is a beautiful crystalline substance which melts to a colourless liquid below the boiling point of water, and boils and volatilises a little above that temperature It dissolves in water and also in alkalies, but it does not appear to form definite compounds with them

OSMOSE (ὠσμος, impulsion) A word used to express the phenomena attending the passage of liquids through a porous *septum*, it includes *endosmose* and *exosmose*, terms which are now seldom used When two saline solutions, differing in strength and composition, are separated by a porous diaphragm or *septum* of bladder, parchment paper, or porous earthenware, they mutually pass through and mix with each other, but they pass with unequal rapidities, so that, after a time, the height of the liquid on each side is different By placing pure water on one side of the septum, and the saline solution on the other, the rate of osmose can be ascertained for any particular salt The following table gives the osmose of one per cent solutions through membrane, each degree being a rise or fall of 1 millimetre (Graham, *Phil Trans*, 1855, p 177)

Oxalic acid,	−148	Chloride of calcium,	+ 20
Hydrochloric acid (0 1 per cent),	− 92	Chloride of barium,	21
Terchloride of gold,	− 54	Chloride of strontium,	26
Stannic chloride,	− 46	Chloride of cobalt,	26
Platinic chloride,	− 30	Chloride of manganese,	34
Chloride of magnesium,	− 3	Chloride of zinc,	54
Chloride of sodium,	+ 2	Chloride of nickel,	88
Chloride of potassium,	18	Nitrate of lead,	125 to 211
Nitrate of sodium,	22	Nitrate of cadmium,	137
Nitrate of silver,	34	Nitrate of uranium,	234 to 458
Sulphate of potassium,	21 to 60	Nitrate of copper,	204
Sulphate of magnesium,	14	Chloride of copper,	351

Stannous chloride, . . .	+289	Ferric acetate, . .	+ 194
Ferrous chloride, . . .	435	Acetate of aluminium, .	280 to 393
Mercuric chloride, . . .	121	Chloride of aluminium, . .	540
Mercurous nitrate, . . .	356	Phosphate of sodium, . .	311
Mercuric nitrate, . . .	476	Carbonate of potassium, . .	436

(See also *Dialysis*)

OXALIC ACID. A white crystalline body of the composition $C_2H_2O_4\ 2H_2O$, which frequently occurs in the vegetable kingdom. It may be prepared artificially by the oxidation of sugar, saw-dust, and many other organic substances. At about the boiling point of water it melts, and at a higher temperature sublimes, with partial decomposition It dissolves readily in water, forming a powerfully acid solution, it unites with bases forming neutral and acid salts In the laboratory it is used as a test for calcium, as this oxalate is quite insoluble in water

Alkaline oxalates are soluble, but most others are insoluble, or difficultly soluble With many metallic solutions oxalic acid acts as a reducing agent, under its influence gold and platinum are reduced to the metallic state, and per salts of mercury, iron, &c, are reduced to protosalts The binoxalate of potassium (C_2HKO_4) is frequently used in the arts It is called *salt of sorrel*

OXAMIDE A light white powder insoluble in cold water and alcohol, but soluble in boiling water, neutral to test paper It is obtained as a precipitate by adding ammonia to oxalic ether, and as a sublimate by the dry distillation of oxalate of ammonia Its composition is $C_2H_4N_2O_2$ Oxamide is the simplest term of a series of oxamides containing alcohol radicals

OXIDATION See *Oxygen*

OXIDE See *Oxygen*

OXYCALCIUM LIGHT See *Lime Light*

OXYCOAL-GAS LIGHT See *Lime Light*

OXYGEN (ὀξύς, acid, and γεννάειν, to produce) The most abundant of all the elements It is a permanent gas, and exists as such in the free state in the atmosphere, being there mechanically mixed with nitrogen and small quantities of other bodies (See *Atmosphere*) Oxygen, in chemical combination, constitutes more than one half of the earth's crust, and is present in water to the extent of eight ninths of the total weight Oxygen was discovered by Priestley in 1774 Atomic weight 16 Symbol O Specific gravity 1 1056 The name was given to it under the impression that it was a necessary constituent of all acids Oxygen gas may be obtained in a variety of different ways, that most usually adopted in laboratories being to heat chlorate of potash (mixed with a little binoxide of manganese) to redness in a tube or retort, when the gas is freely evolved In the pure state oxygen is colourless, transparent, inodorous, and very slightly heavier than atmospheric air Water dissolves it to the extent of 3 per cent by bulk The chemical affinities of oxygen are very intense, and with the exception of fluorine, it will enter into combination with every element In many cases the act of combination is attended with a brilliant exhibition of heat and light, the combustion of phosphorus, charcoal, or iron in oxygen constitutes a brilliant lecture experiment In the compact solid state few metals are acted upon by pure dry oxygen at the common temperature Even sodium remains bright in it, but moisture promotes combination, and in some instances the oxidation gradually eats through the whole mass, a familiar instance of which is seen in the case of iron, which, when freely exposed to the air, is gradually eaten away and converted into red rust, or sesquioxide of iron Oxygen is said to be the great supporter of combustion, and is itself incombustible, but these expressions are only relative, for a jet of oxygen gas will burn in an atmosphere of hydrogen or coal gas just as readily as a jet of the latter will burn in an atmosphere of oxygen It intensifies the combustion of any ordinary combustible substance in a very high degree A splinter of wood, or a taper which has been ignited and then blown out so as to leave only a smouldering red spark at the tip, instantly bursts into flame when introduced into oxygen gas The chemical action of the atmosphere is chiefly due to the oxygen which it contains (See *Atmosphere*) The combinations of oxygen are called *oxides* generally, special names and terminations being given for the sake of distinction Its combinations with the metals are for the most part formed on the type of one or more atoms of water (H_2O), and are called hydrates when containing hydrogen Thus, oxide of potassium K_2O corresponds to H_2O, and the intermediate compound KHO is termed *hydrate of potassium.* Barium forms an oxide on the type of the double water atom H_4O_2, thus we have hydrate of barium $Ba''H_2O_2$, and oxide of barium Ba''_2O_2 On the type of three water atoms, H_6O_3, we have aluminium, the hydrate of which is $Al'''H_3O_3$, the oxide being Al'''_2O_3 On the quadruple water type H_8O_4 we have hydrate of tin (stannic hydrate) $H_4Sn^{iv}O_4$, the oxide (unknown in this case) would be $Sn^{iv}_2O_4$.

On the five atom water type $H_{10}O_5$ we have pentoxide of bismuth Bi''_2O_5. The metallic and non metallic oxides are described in detail under the heading of the respective elements. The substance called ozone is now generally considered to be oxygen in an allotropic condition (See *Ozone*.)

OXYGEN, TRI-, AND TETRA-, ACIDS. According to Dr Odling —

Formula.	Tri-oxacid.	Formula.	Tetra-oxacid.
$HClO_3$	Chloric.	$HClO_4$	Perchloric
$HBrO_3$	Bromic.	HIO_4	Periodic
HIO_3	Iodic	$HMnO_4$	Permanganic
HNO_3	Nitric		
HPO_3	Metaphosphic.	H_2SO_4	Sulphuric.
		H_2SeO_4	Selenic.
H_2SO_3	Sulphurous.	H_2TeO_4	Telluric
H_2SeO_3	Selenious.	H_2MoO_4	Molybdic.
H_2TeO_3	Tellurous	H_2VO_4	Vanadic
H_2VO_3	Vanadous.	H_2WO_4	Tungstic.
H_2CO_3	Carbonic	$H_2Cr_2O_4$	Chromic
H_2SiO_3	Metasilicic.	H_2MnO_4	Manganic
H_2SnO_3	Stannic.	H_2FeO_4	Ferric
H_2TiO_3	Titanic		
H_2TaO_3	Tantalic.	H_3NO_4	Orthonitric
		H_3PO_4	Phosphoric
H_3PO_3	Phosphorous	H_3AsO_4	Arsenic
H_3AsO_3	Arsenious	H_3SbO_4	Antimonic
H_3SbO_3	Antimonious		
H_3BiO_3	Bismuthous (?)	H_4CO_4	Orthocarbonic
H_3BO_3	Boracic	H_4SiO_4	Silicic

OXYGEN, SPECTRUM OF. The spectrum of oxygen, viewed either from a Geissler's tube or from the sparks of an induction coil passing through oxygen gas at ordinary density, consists of a multitude of luminous bands or lines scattered over all parts of the spectrum. Plücker has found that oxygen, like nitrogen, gives spectra of the first, and of the second order according to the temperature of the spark. (See *Spectra of the First Order*, and *Spectra of the Second Order*.)

OXYHYDROGEN BLOWPIPE. When a jet of mixed oxygen and hydrogen gases in the proportion to form water, is forcibly blown through a blowpipe nozzle and ignited, a short colourless flame is produced which has a most intense heating power, and in which a thick platinum wire will melt like wax in a candle, and earths such as lime, magnesia, or zirconia are raised to intense incandescence. Owing to the danger of explosion in case the flame should run back through the jet and communicate with the reservoir of mixed gases, the oxygen and hydrogen are now usually kept in different reservoirs and only allowed to mix at the jet.

OXYHYDROGEN LIGHT. See *Lime Light*.

OZONE (ὄζειν, a scent.) This is supposed to be an allotropic condition of oxygen, but researches on this subject have not yet settled its composition with accuracy, the most recent experiments appearing to show that it consists of a triple atom of oxygen condensed into one, although, according to Williamson and Baumert, it is a tri oxide of hydrogen (H_2O_3). It can be prepared by placing sticks of clean phosphorus in a bottle of oxygen and half covering them with water, or by passing the silent electric discharge through oxygen gas. It may also be prepared by the electrolysis of water and other processes, but by none of these can it be obtained pure, as it is always diluted with a great excess of ordinary oxygen. As far as its properties have been ascertained ozone is a powerful oxidising agent. It attacks and oxidises at the ordinary temperature most vegetable colours, black sulphide of lead, and the metals, mercury, silver, copper, &c. Its action on some metallic peroxides and peroxide of hydrogen is somewhat curious, as in these cases it acts as a reducing agent, giving off oxygen both from the peroxide and from itself, as shown in the following hypothetical equation which represents its action on peroxide of hydrogen —

$$\overset{-}{O}\overset{+}{O}\overset{-}{O} + \overset{+}{H_2}\overset{-}{O}\overset{+}{O} = 2\,\overset{-}{O}\overset{+}{O} + \overset{+}{H_2}\overset{-}{O}$$

Ozone was discovered and has been principally examined by Schonbein. He considered it to be permanently negative oxygen $\overset{-}{O}$, and viewed common oxygen as resulting from the union of ozone and a positive oxygen which he called antozone, thus $\overset{-}{O}\overset{+}{O}$.

P

PALLADIUM A metallic element belonging to the platinum group, discovered by Wollaston in 1803 Atomic weight 126 Symbol Pd It is a white, malleable, and ductile metal Specific gravity 11 4 It melts at a lower temperature than platinum, beginning to fuse at the highest temperature of a wind furnace It oxidises superficially when heated to below redness in the air, but is reduced again at a higher temperature It is soluble in nitric acid It was formerly much used for making the graduated circles of astronomical instruments, as it has nearly the whiteness of silver, and does not tarnish The most remarkable property of palladium is its power of condensing hydrogen in its pores, a solid lump of palladium being capable of absorbing no less than 960 times its bulk of hydrogen gas Graham, to whom this discovery is due, considered this combination to be an alloy of palladium, and hydrogen condensed to the metallic state, or Hydrogenium (See *Hydrogenium*)

PALLAS An asteroid, discovered by Olbers (See *Asteroids*)

PAMPERO A wind blowing across the Pampas of Buenos Ayres towards the sea coast

PANCRATIC EYE PIECE (παν, all , κρατος, strength) An eye piece capable of adjustment so as to obtain a variable magnifying power (See *Eye glass*)

PANCREATIN The active principle of the pancreatic fluid It is a nitrogenous organic substance which has the property of emulsifying oil and fat and rendering them capable of absorption, and it also dissolves starch by converting it into glucose It is a powerful agent of digestion (See *Animal Nutrition*)

PAPIN'S DIGESTER This apparatus was invented in the seventeenth century by Denys Papin, a French physician, and consists of a strong iron boiler provided with a moveable cover, which is capable of being screwed down air tight, and is provided with a safety valve Water is placed in the vessel and heat applied , the consequence is that the water becomes superheated far above the ordinary boiling point as the pressure increases By regulating the safety-valve any desired pressure can be obtained, and the pressure being known, the temperature is also known , thus, if the pressure be 12 atmospheres the temperature of the water will be 374° F , and if 24 atmospheres 435 56° F (See the Table given under the head of *Evaporation*) Papin employed the digester chiefly for extracting the gelatine from bones, which is far more easily dissolved by water at a high temperature than at the ordinary boiling point It can obviously be used for any purpose of digestion or solution

M Cagniard de la Tour has found that at a temperature of 773° F water no longer remains fluid although submitted to the enormous pressure which results from this temperature At a certain temperature all liquids probably assume the gaseous condition in spite of the pressure of their own vapour , thus, at 497 7° F alcohol becomes gaseous, although existing under a pressure of 119 atmospheres, and ether becomes gaseous at 369 5° F under a pressure of 37½ atmospheres (See also *Evaporation*)

PARABOLIC MIRROR A concave mirror of silvered glass or speculum metal, the surface of which is worked to a parabolic curve so as to be free from spherical aberration The reflecting mirrors of astronomical telescopes are always ground and polished to this curvature The production of a true parabolic reflecting surface is one of the most difficult arts of the optician, but it has been overcome with rare skill by Lord Rosse, Mr Lassell, Sir W Herschel, and more recently by Mr Grubb (See Nichol's *Physical Sciences*, article "*Speculum*," also Mr Grubb's paper on "The Great Melbourne Telescope," *Phil Trans* , 1869, part 1 , page 127)

PARABOLIC LENS (παραβολη, παραβαλλω, to compare , παρα, beside, and βαλλω, to throw) A lens ground to a parabolic surface is free from spherical aberration, but the difficulties of grinding this are so great that these lenses are not made Spherical aberration may be overcome by other means (See *Aberration, Spherical*)

PARACENTRIC MOTION When a body is travelling around a centre the resolved part of the body's motion in the direction of the centre, that is, the part of its motion by which its distance from that centre is diminishing or increasing, is called its *paracentric motion*

PARAFFIN (*Parum*, little , *affinis*, affinity) There are several substances known in commerce under this name It is usually applied to a white, solid, translucent substance, free from odour and taste, somewhat crystalline in texture, of specific gravity about 0 87, melting at about 50° C (122° F), and volatilising at a high temperature It is but slightly acted on by reagents, hence its name Its chemical composition is most probably that of a mixture of several hydrides of the higher alcohols—such as cerotene or cerotic hydride ($C_{27}H_{56}$), melene or melinic hydride ($C_{30}H_{62}$)—the lowest of this series being marsh gas, methylic hydride (CH_4) Alcoholic hydrides, as they get lower in the series, become liquid at the common temperature,

and are then known as *paraffin oil* Paraffin is obtained in enormous quantities in the dry distillation of wood, coal, bituminous shale, petroleum, peat, and lignite

PARAFFIN OIL See *Paraffin*

PARALLACTIC INEQUALITY, MOON'S See *Lunar Theory*

PARALLAX. (παραλλάσσω, to shift place) In astronomy, the apparent change of place of a celestial object which would be caused by an apparent change in the observer's position Thus, if an observer at a given station sees a celestial object at one point of the heavens, while an observer, supposed to be at the earth's centre, would see it at another point, the arc between those two points on the celestial sphere is called the *diurnal parallax* of the body, because, as the earth rotates on her axis, the value of the arc would change On the other hand, if a fixed star is seen at a given point on the heavens, while, as supposed to be seen from the sun's centre, it would be at another point, the arc between those points is called the star's *annual parallax*, because it will vary in value as the earth travels round the sun

A moment's consideration will show that the diurnal parallax of a heavenly body, viewed from a given station, will attain its maximum value when the body is on the horizon This maximum value is called the *horizontal parallax* of the body Further, the horizontal parallax will clearly be greatest at the equator The horizontal parallax of a heavenly body, as seen from the equator, is called the body's *equatorial horizontal parallax*

The moon's mean equatorial horizontal parallax is 57′ 4 17″, and therefore, though minute, admits of being readily measured It is not so with the sun, however, whose mean equatorial horizontal parallax is somewhat less than 9″ It is on this account that the determination of the sun's distance is so difficult a problem (See *Sun's Distance*)

The *annual parallax* of the fixed stars is even more minute, and has, in fact, only been determined in the case of one or two stars (See *Stars*)

PARALLEL FORCES See *Composition of Forces*

PARALLEL LINE POSITION MICROMETER This is similar to the *spider thread micrometer*, only there are two spider threads, each of which traverses the field of view, and is moved by a separate screw and graduated milled head. A position circle is sometimes attached to it (See *Micrometer Eye-piece*)

PARALLEL MOTION In the steam engine, a contrivance for changing a reciprocating circular motion into a reciprocating rectilineal motion There are several kinds of parallel motion, the most noted being that invented by Watt, and called by his name It consists of a combination of jointed rods, by means of which the rectilineal motion of the piston rod may produce the oscillation of the beam of the engine Let A denote the end of the beam to which the piston rod is attached, and let us suppose it to be on the right As the beam oscillates about a fixed centre, its extremity, A, describes a circular arc, hence, if the piston rod were attached directly to the beam, it would be exposed to a strain alternately towards the right and left, which would interfere with the efficient working of the engine The object of the parallel motion is to prevent this lateral strain on the piston Let B be a point in the beam near to the extremity A, two equal rods are attached by joints to A and B, and their extremities are jointed to another rod C D, equal in length to A B Thus, A B C D is a jointed parallelogram The point D is connected with the piston-rod Another rod, C E suppose, has one end attached to the joint C, and the other to a fixed point E, as nearly as possible in the plane of the parallelogram, and outside it Now, the joints A and B play in arcs, the centre of which is the middle point of the beam, consequently their convexity is presented to the right The joint C, or *link*, as it is called, moves upon the fixed centre E, and, consequently, plays in an arc whose convexity is presented to the left—that is, contrary to the former While the point A throws the upper end of the link A D to the right, in consequence of the convexity of its play being on that side, the point C throws the end C of the rod C D to the left The action of the first on the point D will tend to move it to the right, and the action of the second motion on the point D will tend to move it to the left Now, the proportion of the lengths of the rods is so nicely adjusted, that the effect of the rod C E in throwing the point D to the left is exactly equal to the effect of the beam in throwing it to the right, and the result of this mutual compensation is, that the point D, to which the end of the piston-rod is jointed, is thrown neither to the right nor to the left, but is moved upwards and downwards in a straight line The utility of the motion therefore depends on the fact that, if the two upper angles of a jointed parallelogram describe arcs about the same centre, and one of the lower angles describes an arc having its convexity opposite to the first, the fourth angular point will move nearly in a straight line The whole line traced out by this point is really a very elongated letter 8, termed in geometry a lemniscate In Watt's parallelogram, the motion of the parts is, however, restricted within such limits as will make the motion of the fourth point differ insensibly from a straight line

White's parallel motion consists of two spur wheels, one of which rolls within the other, the

diameter of the smaller being half that of the latter It may be proved by geometrical reasoning, that if a circle be made to roll within another circle of twice its radius, a point in the circumference of the smaller circle traces out a straight line, which is a diameter of the larger circle, hence, if the end of a piston rod be attached to a point in the pitch circle of White's smaller wheel or pinion as the wheel revolves, the rod will move in a straight line

PARALLELOGRAM OF FORCES The principle that when two forces are represented in magnitude and direction by two adjacent sides of a parallelogram, the resultant is represented in magnitude and direction by the diagonal of the parallelogram passing through the point of application of the forces (See *Composition of Forces*)

PARALLELOGRAM OF VELOCITIES The principle of the composition of velocities If two velocities imparted simultaneously to a particle be represented in magnitude and direction by two adjacent sides of a parallelogram, the resultant velocity will be represented in magnitude and direction by the diagonal of this parallelogram drawn through the particle

PARALLELOPIPED OF FORCES A deduction from the parallelogram of forces, stating that if three forces acting on a point be represented in magnitude and direction by the three sides of a parallelopiped, their resultant will be represented in magnitude and direction by the diagonal of the parallelopiped through the point of application For the resultant of two of the forces is represented by the diagonal of that face of the parallelopiped, of which they form the adjacent sides, and the resultant of this force with the third is represented by the diagonal of the parallelopiped through the point of application (See *Composition of Forces*)

PARALLELS, MAGNETIC See *Magnetic Parallels*

PARAMAGNETIC Faraday, on discovering that all bodies are subject to magnetic influence, and thus doing away with the old distinction into *magnetics* and *non magnetics*, spoke of all substances as being magnetic, and divided them into *paramagnetic* and *diamagnetic* Taking common air and vacuum as a zero, he called paramagnetic all those bodies, such as iron, nickel, cobalt, which, suspended in air, tend with respect to it to move to parts of the magnetic field of greater intensity, and all bodies, like bismuth, which move in air to weaker parts of the magnetic field, he called diamagnetic We have considered the subject as fully as our limits allow under *Diamagnetics* and *Magnetism*

PARANAPHTHALINE See *Anthracen*

PARASELENE (παρα, beside, and σεληνη, the moon) A mock moon The appearance of a luminous disc near the moon, due to the same cause as that which produces parhelia (See *Parhelion*, *Halo*)

PARATARTARIC ACID See *Tartaric Acid*

PARCHMENT PAPER When unsized paper is plunged into a cold mixture of two parts of conc sulphuric acid and one part of water, and after a few seconds removed and well washed in abundance of pure water, it will be found that whilst its chemical composition remains the same (see *Cellulose*) its physical properties are entirely altered It is converted into a tough membranous body resembling parchment, hence its name, whilst its strength is enormously increased, so that a strip which originally would not support more than three or four pounds weight when dry, and scarcely an ounce when wet, will now carry over thirty pounds either wet or dry Parchment paper is now largely manufactured, and it is of great use for replacing parchment, as well as for covering jam pots, &c To the chemist it is invaluable as forming the most efficient *septum* for the process of *dialysis*

PARHELION (παρα, beside, and ἥλιος, the sun) A mock sun It is due to the same phenomena of refraction as those which produce *halos* and *paraselenæ* Sometimes a white band parallel to the horizon is seen crossing the sun, and possessing about the width of its disc At each extremity is a luminous image of the sun, sometimes coloured like halos Tangent circles sometimes proceed from these discs Marriotte considered that all these phenomena are due to refraction through crystals of ice, and calculation appears to confirm this view (See *Halo*, and *Paraselene*)

PARTIAL CURRENT See *Derived Currents*

PARTIAL DISPERSION A term used to express irrationality of *dispersion* (which see) The total dispersions of sulphuric acid and oil of cassia prisms, for instance, may be the same, but their partial dispersions, comparing similar colours, are very different

PARTIAL ECLIPSE See *Eclipse*

PARTIAL POLARISATION See *Polarisation, Partial*

PASCAL'S LAW OF PRESSURE See *Pressure through Liquids*

PATH OF A PROJECTILE See *Projectile.*

PATTINSON'S PROCESS See *Lead*

PAVO. (The Peacock.) One of Bayer's southern constellations. It is remarkably rich in

lucid stars, and is one of the few modern constellations which bears any resemblance to the object with which it has been associated

PEARL ASH See *Carbon, Carbonate of Potassium.*

PEARL WHITE See *Bismuth*

PEGASUS One of Ptolemy's northern constellations, represented under the figure of a winged horse, whose hind quarters however do not appear in the maps Three of the stars of this constellation, (Alpha, Beta, and Gamma), form with Alpha Andromedæ a conspicuous square According to Bayer's lettering the star Alpha Andromedæ is Delta Pegasi

PELOPIUM See *Columbium*

PENDULUM (*Pendeo*, to hang, suspend, *pendulum*, a small suspended body) Pendulums are of several kinds When a small heavy particle is attached by a fine thread to a fixed point it forms a simple pendulum Suppose, for example, a small bullet to be suspended by a very fine thread, and caused to oscillate in an arc not exceeding 2°, then the bullet will observe the laws of the simple pendulum, (1) the motion will be isochronic, (2) the time of an oscillation will be independent of the weight of the particle, (3) will vary as the square root of the length of the string, and (4) will vary inversely as the square root of the force of gravity at the locality in which the experiment is made Hence, in the same place, the seconds' pendulum is always of the same length, but, in consequence of the variation of gravity, is different for different points on the earth's surface The length of the seconds' pendulum in London is 39 047 inches

By the third law, a pendulum one fourth of this length will oscillate twice in a second, a pendulum one ninth of the length, three times in a second, and so on

Pendulums in which the vibrating body is of considerable size are termed compound pendulums Suppose a block of wood to be so attached by a point in it that it is free to oscillate in a certain plane Let the time of a small oscillation be accurately noted, and determine the length of the simple pendulum which would make a small oscillation in the same time This length is called the "length of the simple equivalent pendulum" Suppose in the body a point be taken at a distance from the fixed point equal to the length of the simple equivalent pendulum This point is called the centre of oscillation, and the fixed point the centre of suspension The line joining the two centres passes through the centre of gravity of the body It is an important law that the centres of oscillation and suspension are convertible, and the time of oscillation about each is the same The simplest body which will serve as an illustration is a straight rod or wire If the rod be attached at one extremity the time of oscillation will be the same as that of a simple pendulum having two thirds of its length Hence by the above law we see that the time of oscillation will be the same, whether the rod be suspended from either extremity or at either of the points found by dividing the rod into three equal parts The oscillations of a rigid body have been made use of to determine the force of gravity at different points on the earth's surface It has been shown that the time of oscillation varies directly as the square root of the simple equivalent pendulum, and inversely as the square root of the acceleration due to gravity Hence this acceleration can be determined as soon as the length and time are known Accurate experiments have been made on this plan by Captain Kater, (see *Phil Trans* 1818, and *Encyc Metrop*), and again with a correction for the attraction of the intervening land, so as to give a value for the acceleration at the level of the sea, by Dr Young, (*Phil Trans* 1819), also by the Astronomer Royal, in Harton coal pit in 1854, (see *Phil Trans* 1856) For still more accurate corrections see *Phil Trans* 1831, and Cambridge *Phil Trans* vol. ix.

The experimental determination of the length of the seconds' pendulum has also been applied to furnish a standard of length which shall be invariable, and capable of recovery at any time By an Act of Parliament, 5 Geo IV, the yard is defined as 36 parts, of which there are 39 1393 in the length of a pendulum vibrating seconds of mean time in the latitude of London in vacuo at temperature 62° F

For a third use see *Horology*

PENETRATION, ELECTRIC, or, *Penetration of Charge* The phenomenon of the *residual charge* in a Leyden jar is explained on the supposition that owing to the intensely strained condition under which they are, the molecules of the dielectric become bodily charged to a small extent, the electricity of the jar, as it were, penetrating the glass When the jar is discharged, this electricity is again forced outwards to the coatings, the molecules of the glass tending to return to their normal condition. To investigate the laws of the phenomenon a plate of insulating material is furnished with removeable metallic coatings These are charged, allowed to remain so for some time, and then discharged and removed. At first no signs of electricity are discovered on the surfaces of the dielectric, but by degrees they appear, as may be ascertained with the proof plane, each side becoming electrified in the same

way as its coating was It is found that the amount of penetration increases with the intensity of the original charge, and with the length of time it has been allowed to act, it also depends on the nature of the insulator Faraday showed that the residual charge was greatest with paraffin, greater with shell lac than with glass, and greater with glass than with sulphur

PENUMBRA (*Pene*, almost, and *umbra*, a shadow) In astronomy, a partial shadow Thus, in a lunar eclipse those parts of the moon which are illumined by a portion, but not the whole of the solar disc's light are said to be in the earth's penumbra In a solar eclipse those parts of the earth which are illumined by a portion, but not the whole of the solar disc are in the moon's penumbra Those parts of sun spots which are less dark than the umbra are termed the penumbra (See also *Shadow*)

PEPSIN The active principle of the gastric juice Its peculiarity is that, in the presence of an acid, it converts almost every description of albuminous and fibrinous matter into a soluble form of albumen, which is capable of very easy absorption (See *Animal Nutrition*)

PERCHLORIC ACID See *Chlorine*

PERCUSSION (*Percussio*) The act of striking one body against another The shock arising from the collision of two bodies (See *Impact*)

PERIGEE (περί, near by, and γῆ, the earth) In astronomy that part of the moon's orbit which is nearest the earth (See *Apogee*)

PERIHELION (περί, near, and ἥλιος, the sun) That point of the orbit of any planet, comet, or meteor, which is nearest to the sun

PERIOD (περίοδος, a going round) In astronomy the interval of time occupied by a planet or comet in travelling once round the sun, or by a satellite in travelling round its primary

PERISCOPIC SPECTACLES (περι, around, and σκοπεω, to see) A form of spectacles invented by Dr Wollaston The lenses are of meniscus shape, and give a wider field than double convex or double concave glasses (See *Spectacles*)

PERMANENT VIBRATIONS, or, as they are sometimes called, *stationary* vibrations, are distinguished from *progressive* vibrations, or waves of varying density and tension Thus, if an elastic rod fastened at one end be set in vibration, all portions of the rod move together, and in the same direction They commence moving at the same time, continue moving for the same time, arrive at their respective positions of maximum disturbance at the same time, and commence simultaneously their return journey Such vibrations are called stationary or permanent If, however, (see *Propagation of Sound*) a state of compression passes through a medium, the portions of the medium nearer to the sonorous body will be the first to be affected, and those more remote will be influenced subsequently according to their distance from the sonorous body Such vibrations are called progressive All undulations are progressive

PERPETUAL MOTION A chimerical idea which has possessed the human mind in former times, and is at present occasionally held by persons having insufficient knowledge of mechanical science, to the effect that it is possible to obtain a machine which will continue to do external work without the application of external energy The subject has held a place in physics similar to that occupied in chemistry by the search for the "elixir of life," and for a method of changing the baser metals into gold Every machine when in action does work, for it is impossible to construct a machine in which there is a total absence of friction, and if no other work be done, the machine has to overcome the friction and other resistances to the motion of its parts The performance of work involves the transmutation of one form of energy into another, and the total amount of energy of the machine when left to itself is diminished by that which it parts with in the transformation Hence, it is only possible to obtain from a machine that is not regularly supplied with energy from without, a definite and limited amount of work, in other words, perpetual motion is impossible (See *Energy, Conservation of Energy*)

PERSEUS One of Ptolemy's northern constellations This asterism is exceedingly rich, and contains many objects of great interest The splendid double cluster of stars in the sword handle of Perseus is perhaps the most amazing group of stars in the heavens Even a small telescope reveals a large number of stars within the group, but in a good telescope the clusters exhibit an amazing richness of stellar aggregation The star Algol is another remarkable feature of this constellation The variations of this orb are described elsewhere (See *Stars, Variable*)

PERSIAN WHEEL A machine for raising water by means of the action of a stream of water on a wheel It consists of an ordinary water wheel, having buckets attached at regular intervals around a circle near the circumference The buckets are not firmly fastened, but are hung upon strong projecting pins Suppose the wheel to turn in the same direction as the hands of a watch, then the buckets descend on the right and go down into the water, where they are filled and ascend on the left till they reach the top Here they come in contact with the end of a fixed trough, and are turned over so as to empty the water into the trough, from

which it is conveyed by pipes As each bucket passes the trough it falls again into the vertical position, and so goes down empty into the stream, where it is filled as before

In another form of the wheel used to raise water only as high as the axis, the buckets are replaced by curved hollow spokes, which, in the lowest position, have their convexity directed downwards As the wheel turns, the water rises in the hollow spokes, and runs out into a trough placed immediately below the axis

PERSISTENCE OF VISUAL IMPRESSION The retina will receive a luminous impression instantly, an electric spark lasting the millionth part of a second is plainly seen, but the eye does not lose an impression with equal rapidity, for it requires about one third of a second for the impression to subside It follows from this that a luminous point passing across the field of view in a less time than this, appears drawn out to a luminous line, thus forked lightning appears a continuous line of light, and shooting stars are also elongated to lines If two pictures are successively presented to the retina with great rapidity, they become superposed owing to this property, the thaumatrope, phenakistoscope, and zoetrope are toys based on the phenomena of persistence of vision

PHACT (Arabic) The star α of the constellation Columba

PHANTASMAGORIA (φαντασμα, an appearance, from φαινω, φαω, Sans *bha*, to shine and αγοραομαι, to gather) A term applied to the effects produced by a magic lantern, sometimes also to representations of shadows of persons and objects thrown upon a semi transparent screen

PHASE (φάσις, appearance) In astronomy the aspect of the moon or planets as respects the apparent figure of the luminous portion of their disc

PHECDA (Arabic) The star γ of the constellation Ursa Major

PHENAKISTOSCOPE An optical toy devised by Plateau, in which a series of images are placed before the eye, one after the other the other, in rapid succession The images are made to represent the different stages of motion, such as a man in the act of running, a horse leaping, &c &c Owing to the persistence of impressions on the retina, one image does not cease to be seen before the next is presented to the eye, and the result is an apparent continuity of motion, the object appearing to be moving A recent modification of this toy is known as the *zoetrope* (See *Persistence of Visual Impression*)

PHENAMIDE See *Aniline*

PHENOL See *Carbolic Acid*

PHENYLAMINE See *Aniline*

PHENYLIC ACID See *Carbolic Acid*

PHENYLIC ALCOHOL See *Carbolic Acid*

PHLOGISTON (φλογιζω, to inflame) A term used by Stahl to designate the matter or principle of fire The celebrated *theory of phlogiston*, (which influenced science for more than a century), affirmed that various changes produced by chemical operations, were due to the absorption or rejection of this principle of fire by the substances acted upon The assimilation of phlogiston means, in the language of modern chemistry, deoxidation, while loss of phlogiston means combination with oxygen gas Thus, lead during calcination was said to lose phlogiston, for lead was regarded by the followers of this theory as calx (i e, oxide) of lead, *plus* phlogiston and the heating of lead with substances rich in phlogiston (such as charcoal) caused the phlogiston to be absorbed, and the metal is the result The following paragraph as to the influence of the theory of phlogiston is from a paper on the subject by Mr Rodwell (*Philosophical Magazine* for January 1868), to which the reader is referred for further information —"Of the influence of the theory of phlogiston I need say but little It was not the first chemical theory, it did not give the first explanation of combustion, and it was established in the face of facts which carried with them its refutation When the first stage of its development was passed, facts were adapted to the theory, and phenomena were tortured and garbled so as to fit in with it, by which means the progress of chemical science was somewhat retarded Even when Lavoisier had conclusively proved the fallacy of the theory, this blind adherence shut the eyes of the phlogistians to the merits of the new system, and to the utter falsity of their own Nevertheless, the theory exercised influence for good, for by its means a certain amount of order was introduced among a vast chaotic mass of chemical facts, and phenomena were classed together and reasoned upon together, and together submitted to similar processes of mental analysis, after the manner so strongly advocated by Francis Bacon"

PHŒNIX (*The Phœnix*) One of Bayer's southern constellations

PHONAUTOGRAPH (Scott and Konig's) The method of registering the vibrations of sonorous solids by means of sinuous lines (see *Sinuosities*) has been extended to aerial vibration A deep paraboloid of revolution is truncated by a plane, so as to form a parabolic cup with a flat bottom In the centre of the bottom a hole is cut, into which a short tube is fitted The [illegible]

of this tube is closed by a membrane of tightly stretched caoutchouc or gold beater's skin, the tension of which can be varied by a ring Fastened to the outside of the membrane is a feather, which is in contact with a revolving cylinder blackened on its surface, and working on a screw axis (See *Sinuosities*) A little stiff arm can be brought into contact with the membrane so as to insure the occurrence of a loop and absence of a node, when the membrane vibrates at the point where the feather is fastened When a note is sounded in such a way that some of it is collected in the paraboloid, the vibrations are communicated to the drum membrane, and thence to the feather If, at the same time, the blackened cylinder is turned, a sinuous line is produced (See *Sinuosities*) By this instrument the joint effect of two or more simultaneous notes can be examined Thus, if a note and its octave are sounded together, a compound sinuosity is produced, every alternate hill of which is twice as high as the intermediate hills Scott's phonautograph is admirably adapted for showing graphically the recurrence of beats at regular intervals, and the relation of these to concord and discord Thus, if one note consists of two or three more vibrations in a second than another, we hear of course two or three beats in a second (see *Beats*), and we find on the blackened paper when such notes are sounded together two or three hills of augmented height in the length of sinuosity which represents the second of time The variations of loudness, duration, and pitch which constitute melody can be recorded by this instrument

PHOSGENE GAS (φως, light, γενναω, to produce) Known also as chloro-carbonic acid, and oxychloride of carbon, is formed by exposing a mixture of chlorine and carbonic oxide to the sun's rays, whence its name It is a colourless gas, having a suffocating odour Specific gravity 3 4249, formula CO, Cl_2, water decomposes it, yielding hydrochloric and carbonic acids

PHOSPHORESCENCE (φως, light, and φερω, to carry) Under some circumstances, bodies become capable of emitting light when viewed in the dark The light is generally unaccompanied by heat, and is seldom the result of chemical action Phosphorescence may be excited by heat—for instance, in the diamond, fluorspar, &c Many bodies are rendered phosphorescent by an electric discharge, such are sugar, Canton's phosphorus, &c Other substances are rendered phosphorescent by mechanical action, thus many crystals emit light when they are broken Exposure to the sun, or other intense light, is another cause of phosphorescence Many artificial phosphori are prepared which shine with very beautiful colours under these circumstances The same effect is also produced by the electric discharge, and minute residues of gases in Geissler's tubes, excited in that manner, produce very beautiful effects The rays which produce phosphorescence are of high refrangibility, and the light emitted by phosphorescent bodies is of lower refrangibility, and concentrated into a few luminous bands of the spectrum The luminous appearance of phosphorus in the air is generally considered to be due to slow oxidation Phosphorescence lasts from a fraction of a second to some hours

PHOSPHOROSCOPE (φως, light, φερω, to carry, and σκοπεω, to view) An instrument devised by E Becquerel for detecting the phenomena of phosphorescence in bodies which only shine a fraction of a second after insolation By means of a disc, perforated in a particular manner, and revolving over a box containing the substance under examination, sunlight may be allowed to fall upon it, and be cut off again immediately before the observer can see it through the other aperture By rotating the disc with sufficient rapidity, the examination may be made at an interval less than the 400th part of a second after the light has ceased to shine upon the substance (See Miller's *Physics*, 1867, p 193)

PHOSPHORUS (φως, light, and φερω, to bring) A non metallic element discovered in 1669 by Brandt Atomic weight, 31, symbol, P, specific gravity, 1 82 In the pure state it is a nearly colourless or faintly yellow, waxy solid It is transparent, although it soon becomes opaque and crystalline It crystallises in octahedrons It melts at 44° C (111° F) to an oily liquid, and boils at about 290° C (554° F) Vapour density about 4 35 It is insoluble in water, but very soluble in disulphide of carbon, and less so in benzol and volatile oils It is a very poisonous substance The most striking characteristic of phosphorus is its intense affinity for oxygen A piece of it catches fire by slight friction or gentle heat, and sometimes spontaneously when exposed to air on wood or some non-conductor of heat When its solution in disulphide of carbon is poured upon blotting paper and exposed to the air the finely divided phosphorus which is left behind oxidises quickly, and bursts into flame The combustion of phosphorus in oxygen is attended with the evolution of one of the most intense artificial lights known When exposed to air in a dark room phosphorus shines with a pale, lambent light, evolving a faintly luminous vapour Owing to its great inflammability, phosphorus should always be kept under water, and must only be handled with extreme care Phosphorus exists in several modifications, which are as follows — *White Phosphorus* is produced by the action of light Its specific gravity is less than that of the transparent variety. *Black Phosphorus* is produced by melting phosphorus and suddenly

cooling it It is reconverted into ordinary phosphorus by refusion and slow cooling *Viscous Phosphorus* is obtained by heating phosphorus to near its melting point and then suddenly cooling it *Amorphous Phosphorus* is obtained by keeping ordinary phosphorus for 30 or 40 hours at a temperature of about 232° C (450° F) under pressure in an atmosphere of carbonic acid When purified it is a red, amorphous substance, of specific gravity 2 14, which does not oxidise in the air at the ordinary temperature, emits no odour, is not poisonous, and is insoluble in disulphide of carbon and other solvents of ordinary phosphorus It may be kept in the air without danger, and can even be wrapped in paper and handled without fear of ignition At a temperature of 260° C (500° F) it is reconverted into ordinary phosphorus Owing to its comparative harmlessness amorphous phosphorus is largely replacing common phosphorus in the manufacture of lucifer matches Phosphorus forms many important compounds, amongst which the following deserve mention —

Hypophosphorous Acid (H_3PO_2) is a viscid liquid, having strongly acid properties, uniting with bases to form a well defined series of salts, some of which are used in medicine The principal hypophosphites are—*Hypophosphite of Calcium* ($CaP_2H_4O_4$), which crystallises in colourless prisms, soluble in water, and permanent in the air *Hypophosphite of Potassium* (KPH_2O_2) is very deliquescent, but may be obtained in crystalline plates

Phosphorous Acid (anhydrous, P_2O_3, hydrated, H_3PO_3), forms a series of salts with bases, which are, however, of little importance

Phosphoric Acid (P_2O_5) is produced when phosphorus burns in air or oxygen It is a very light white amorphous substance, extremely deliquescent in moist air, and hissing like a red hot iron when thrown into water It is a powerful acid, and has different properties according to the number of atoms of water with which it unites The compound $P_2O_5\ H_2O$ is called *Metaphosphoric Acid*, the compound $P_2O_5\ 2H_2O$ *Pyrophosphoric Acid*, whilst the compound $P_2O_5\ 3H_2O$ is called *Orthophosphoric Acid*, or ordinary phosphoric acid Each of these acids forms a series of salts with bases The following are the most important —*Orthophosphate of Aluminium*, or turquoise, has the composition $2Al_2O_3\ P_2O_5\ 5H_2O$, its specific gravity is 2 6, and it has a peculiar waxy lustre and a bluish green colour, owing to the presence of a little copper When fine, it is highly prized as a gem *Orthophosphate of calcium* $3CaO\ P_2O_5$ is the principal constituent of bone ash, and is also met with in considerable quantity in coprolites When prepared artificially, it is a white earthy powder insoluble in water, but slightly so in the presence of carbonic acid It is dissolved and decomposed by most acids The mineral apatite consists of a mixture of orthophosphate of calcium and chloride of calcium, some of the chlorine being frequently replaced by fluorine *Phosphates of Magnesium* —The neutral orthophosphate ($Mg_3P_2O_8$) is precipitated as an insoluble powder, when a magnesia salt is mixed with a soluble orthophosphate The best known magnesium compound is, however, a double phosphate of magnesium and ammonium $(NH_4)_2\ Mg_2P_2O_8\ 12H_2O$, which is the precipitate produced when a magnesium salt is mixed with an alkaline orthophosphate, and ammonia, in the presence of sal-ammoniac It is a heavy crystalline precipitate, which, from its insolubility in water, is almost always used for the quantitative estimation of phosphoric acid, or magnesium *Phosphates of Silver* —Orthophosphate of silver (Ag_3PO_4) is a lemon-yellow insoluble powder Pyrophosphate of silver ($Ag_4P_2O_7$) is a white insoluble powder The metaphosphate of silver is also white and insoluble These differences of colour serve to distinguish the three modifications of phosphoric acid *Phosphates of Sodium* —These are very numerous and complex in composition The crystallised metaphosphate has the composition $3Na_2O\ 3P_2O_5\ 12H_2O$ It crystallises in large rhombic prisms, easily soluble in cold water Orthophosphate of sodium, or the ordinary phosphate, has the composition $Na_2HPO_4\ 12H_2O$ It crystallises in large prisms, which effloresce in the air, they dissolve easily in cold water, forming a solution which has a saline taste, and is frequently used in medicine This phosphate unites with ammonia to form the salt known as *phosphorus salt* or *microcosmic salt*, having the composition $Na(NH_4)HPO_4\ 4H_2O$ It crystallises in monoclinic prisms, which dissolve easily in water, when heated the water and ammonia are driven off, and pure metaphosphate of sodium is left behind This is frequently used as a flux in blowpipe experiments, instead of borax, as the fused metaphosphate dissolves metallic oxides, frequently with characteristic colours *Pyrophosphate of Sodium* —This salt ($Na_4P_2O_7\ 10H_2O$) is easily obtained by igniting the salt last mentioned, dissolving in water and crystallising Phosphoric acid also unites with alcohol radicals and other organic compounds

Chlorides of Phosphorus —Phosphorus and chlorine unite readily at the common temperature with evolution of heat and light When the phosphorus is in excess, the *trichloride* (PCl_3) is formed, which is a thin colourless liquid of specific gravity 1 6 boiling at 78° C (172° F), and decomposed by water into hydrochloric acid and phosphorous acid With excess of chlorine the *pentachloride of phosphorus* (PCl_5) is formed, which is a solid straw yellow crystalline mass

subliming at 100° C (212° F), and decomposed by water into hydrochloric and phosphoric acids Pentachloride of phosphorus is a valuable re-agent in organic chemistry, as under its influence many alcohols and acids are converted into chlorides of their radicals

Phosphorus unites with hydrogen to form a gaseous compound PH_3, a liquid compound PH_2, and a solid compound P_2H

PHOSPHORUS, ACTION OF LIGHT ON Schrœtter has shown that ordinary phosphorus is converted into the red amorphous, insoluble variety, by the prolonged action of sunlight

PHOSPHORUS BASES In its chemical reactions phosphorus acts in many instances like nitrogen, and, as above stated, forms with hydrogen a gaseous compound (PH_3) which has some of the properties of ammonia, and like ammonia can have one, two, and three of its atoms of hydrogen replaced by an alcohol radical, forming what are call phosphorus bases These have much stronger basic properties than phosphuretted hydrogen, and are extremely numerous indeed they are as practically unlimited as the ammonia bases They mostly unite with acids forming crystallisable salts Only one base has yet shown properties which appear likely to render it of value, and this is the one in which the three equivalents of hydrogen in PH_3 are replaced by ethyl (C_2H_5), forming the compound $(C_2H_5)_3P$, or *Triethyl Phosphine*

PHOSPHORUS SALT See *Phosphorus*

PHOSPHORUS, SPECTRUM OF This may be obtained by passing an induction current through a perfectly exhausted Geissler's tube containing a piece of phosphorus On warming the phosphorus it rises in vapours and the current passes In the spectroscope the light thus produced is seen to consist principally of three bands in the green Phosphorus gives *spectra of two orders*, similar to nitrogen (See *Nitrogen, Spectrum of*)

PHOTO-CHEMICAL INDUCTION A term employed by Professors Bunsen and Roscoe to express an effect which they first observed when experimenting on the action of light upon a mixture of hydrogen and chlorine (See *Chemical Photometer*) No action was found to take place during the first moment or two, it then commenced and rapidly increased to a maximum A similar action has been observed in other photo chemical processes

PHOTO GALVANOGRAPHIC PROCESS See *Photographic Engraving*

PHOTOGLYPHIC ENGRAVING See *Photographic Engraving*

PHOTOGRAPHIC ENGRAVING There are many processes by which a metal plate can be engraved, sufficient to print from, by the joint action of light and chemical force It would be impossible to describe the numerous ingenious processes which have been from time to time devised for this purpose, but the following outline will give a fair idea of the principles on which most of them are based —A solution is made of gelatine and bichromate of potash of appropriate strength This is poured, whilst warm, upon a steel plate, and allowed to dry in the dark It is next exposed to light under a negative The action of light causes the chromic acid to be reduced to sesquioxide of chromium, the oxygen going to the gelatine, and converting it into an insoluble substance If the surface is now wetted, the portions not acted on by light will swell up the other parts remaining at their original level, and a mould can be taken of this relief picture, and from this a copper plate electrotyped, from which prints may be taken at an ordinary press This is the principle of the *photo-galvanographic process* If instead of simply allowing the unacted on gelatine to swell up, it is entirely dissolved out with water, the portion where no light has acted will be left bare, and may be bitten in with acid Those parts covered with the insoluble gelatine being protected from action, this engraved plate may then be printed from at a copperplate press in the ordinary manner If, instead of metal, a lithographic stone is employed, and it be moistened with water after the action of light, the different parts will have different attractions for grease and water, and *photo lithography* is the result. Mr Talbot pours the mixture over a steel plate, and, after exposure to light, floods it with solution of perchloride of iron This soaks through the unaltered gelatine, and etches the steel surface sufficiently deep to enable it to be printed from This he calls *photoglyphic engraving* Mr Woodbury takes a leaden mould from the swollen-up gelatine picture, and uses this to print from with gelatine ink in a very ingenious manner This is called the *Woodbury type* There are many other processes of this kind, but the principle is the same in all

PHOTOGRAPHIC TRANSPARENCY Bodies which appear perfectly transparent and colourless to the ordinary rays of light, have very different transparencies to the photographic or actinic rays Thus, rock crystal will transmit rays of the spectrum of the highest known refrangibility, whilst a piece of common glass interposed immediately cuts down the spectrum to about half its length This subject has been principally examined by Dr W A Miller (See *Proceedings of the Royal Institution*, March 6, 1863) Among the most remarkable results upon the photographic transparency of bodies which have been observed in these researches are the following —1 Colourless solids, which are equally transparent to the visible rays, vary greatly in permeability to the chemical rays 2. Bodies, which are photographically transparent in the

solid form, preserve their transparency in the liquid and in the gaseous states 3 Colourless transparent solids which absorb the photographic rays, preserve their absorptive action with greater or less intensity both in the liquid and in the gaseous states 4 Pure water is photographically transparent, so that many compounds which cannot be obtained in the solid form sufficiently transparent for experiments, may be subjected to trial in solution in water The mode in which the experiments were conducted is the following —The source of light employed was the electric spark taken between two metallic wires, generally of fine silver, connected with the terminals of the secondary wires of an induction coil, into the primary circuit of which is introduced a condenser, and into the secondary circuit a small Leyden jar The light of the sparks is then allowed to fall upon a vertical slit, either before or after traversing a slice or stratum of the material, the electric transparency of which is to be examined The transmitted light is then passed through a quartz prism, placed at the angle of minimum deviation Immediately behind this is a lens of rock crystal, and behind this, at a suitable distance, the spectrum is received upon the sensitive surface of collodion Liquids are contained in a small glass cell with quartz faces, and gases and vapours in long tubes, closed at their extremities with thin plates of polished quartz The following tables exhibit the relative diactinic power of various solids, liquids, and gases and vapours —

PHOTOGRAPHIC TRANSPARENCY

Solids		Liquids		Gases and Vapours	
Rock crystal,	74	Water,	74	Oxygen,	74
Ice,	74	Alcohol,	63	Nitrogen,	74
Fluor spar,	74	Chloroform,	26	Hydrogen,	74
Topaz,	65	Benzol,	21	Carbonic acid,	74
Rock salt,	63	Wood spirit,	20	Olefiant gas,	66
Iceland spar,	63	Ether,	16	Marsh gas,	63
Sulphate of magnesia,	62	Acetic acid,	16	Coal gas,	57
Borax,	62	Oil of turpentine,	8	Benzol vapour,	55
Diamond,	62	Bisulphide of carbon,	6	Hydrochloric acid,	53
Bromide of potassium,	48			Hydrobromic acid,	23
Thin glass,	20			Hydriodic acid,	15
Iodide of potassium,	18			Sulphurous acid,	14
Mica,	18			Sulphuretted hydrogen,	14
Nitrate of potash,	16				

Diactinic bases, when united with diactinic acids, usually furnish diactinic salts, but such a result is not uniformly observed, the silicates are none of them as transparent as silica itself in the form of rock crystal Again, hydrogen is eminently diactinic, and iodine vapour, notwithstanding its deep violet colour, is also largely diactinic, but hydriodic acid gas is greatly inferior to either of them The same substance, however, whatever may be its physical form, whether solid, liquid, or gaseous, preserves its character, no chemically opaque solid, though transparent to light, becomes transparent photographically by liquefaction or volatilisation, and no transparent solid is rendered chemically opaque by change of form Hence it is obvious that this opacity or transparency is intimately connected with the atomic or chemical character of the body, and not merely with its state of aggregation Although the absorption of the chemical rays varies greatly in different gases, which, therefore, in this action display an analogy to their effects upon radiant heat, yet those gases which absorb the rays of heat most powerfully are often highly transparent to the chemical rays, as is seen in the case of aqueous vapour, of carbonic acid, cyanogen, and olefiant gas, all of which are compound substances, not chemical elements In the case of reflection from polished surfaces the metals are found to vary in the quality of the rays reflected, gold and lead, although not the most brilliant, reflecting the rays more uniformly than the brilliant white surfaces of silver and speculum metal

PHOTOGRAPHS OF THE SPECTRUM See *Actinism*

PHOTOGRAPHY (φως, light, and γραφω, to write) The art of producing representations or pictures of objects by means of light Photographs are divided into positive and negative A negative is one in which the light and shade are reversed, and a positive is one in which they are shown as in nature The action of light being to darken a sensitive surface, the picture which is taken in the *camera obscura* is a negative, and by using this as a matrix, superposing it on another sensitive surface and exposing the whole to light, a negative of this negative is produced, which is a positive Thus, from the original negative taken in the camera any number of positives may be printed Under the heads *Calotype, Collodion Process*, and *Daguerreotype*, will be found an outline of the principal photographic processes

PHOTO-LITHOGRAPHY. See *Photographic Engraving.*

PHOTOMETER, BUNSEN'S. See *Bunsen's Photometer.*

PHOTOMETER, CHEMICAL. See *Actinometer.*

PHOTOMETER, POLARISATION. See *Polarisation Photometer.*

PHOTOMETRY. (*φως*, light, and *μετρον*, a measure.) Photometry consists of the measurement of the luminous intensity of light. It may be either *absolute* or *relative*. 1. Given a luminous beam, it is required to express its intensity by some *absolute* term having reference to a standard obtained at some previous time, and capable of being reproduced with accuracy at any time. This is absolute photometry. 2. The standard of comparison is compared separately at each observation, and the problem then consists in the determination of the *relative* intensities of two sources of light. The *absolute* method has scarcely yet been attempted, nor does it seem probable that the problem will be solved for some considerable time. The relative method has, however, been brought to considerable perfection, and the various instruments now in use are described under their separate headings. (See *Bunsen's Photometer, Polarisation Photometer, Rumford's Photometer, Ritchie's Photometer, Arago's Photometer, Jet Photometer, Electro-Photometer, Masson's.*)

PHYSICAL ANALYSIS OF EXPIRED AIR. Professor Tyndall found that carbonic acid possesses very slight absorptive power for the heat emitted from hot solids, but that, when a flame of carbonic oxide (burning to carbonic acid) was substituted as the source, the absorption of the emitted heat by carbonic acid was considerable. Thus, one thirtieth of an atmosphere of carbonic acid absorbs 48 per cent. of the radiation from a carbonic oxide flame, and one third of an atmosphere absorbs 74.3 per cent. It is clear, therefore, that a very small quantity of carbonic acid can be detected by observing its absorption of the heat emitted by a carbonic oxide flame. This has been applied by Mr. W. F. Barrett to the analysis of expired air, which leaves the lungs charged with aqueous vapour and carbonic acid. The absorption due to dry expired air was first determined, and a mixture was then made of pure carbonic acid with dry air, which produced a similar absorption. Two determinations by Professor Frankland of the carbonic acid in expired air, by chemical analysis, gave respectively 4.66 and 5.33 per cent., while the physical analysis of the same by Mr. Barrett, gave respectively 4.56 and 5.22.

PICRIC ACID, or, *Carbazotic Acid.* An organic acid largely used as a yellow dye for wool and silk. It forms light yellow octahedrons and needles, of the composition $C_6H_3N_3O_7$. It is slightly soluble in water, easily so in alcohol. Its solutions have a harsh bitter taste. Picric acid is sometimes used as a test for potassium, as its potassium salt is very slightly soluble in cold water. Picrate of potassium detonates violently when heated, and has been used as an explosive agent.

PICROTOXIN. A poisonous organic substance extracted from the seeds of *cocculus indicus*. Composition $C_{12}H_{14}O_5$. It crystallises in stellate groups, which are white, inodorous, and neutral. Its taste is intensely bitter.

PICTOR. (Abbreviated from *Equuleus Pictorius*, the painter's easel.) One of Lacaille's southern constellations.

PIEZOMETER. See *Compressibility of Liquids.*

PIG IRON. See *Iron.*

PIGMENTUM NIGRUM. (Black pigment.) An opaque coating which covers the choroid coating of the eye. (See *Eye.*)

PILE, DRY. See *Dry Pile.*

PILE, VOLTA'S. See *Volta's Pile.*

PINION. See *Rack and Pinion.*

PISCES. (The fishes.) A sign of the zodiac. The sun enters this sign on about the 19th of February, and leaves it on about the 21st of March. The constellation of the same name occupies the zodiacal region corresponding to the sign Aries. Within this constellation are several very interesting double stars, among which the star Alpha Piscium, a well known binary, is worthy of special mention.

PISCIS AUSTRALIS. (The southern fish.) One of Ptolemy's southern constellations. Its chief brilliant is the star Fomalhaut, commonly recognised as a first-magnitude star, but estimated by Sir John Herschel as one of the second magnitude only, though nearly the brightest of the class.

PISCIS VOLANS. (The flying fish.) One of Bayer's southern constellations.

PITCH, in music, in the general sense, is the number of vibrations per second which constitute a note. Thus, the pitch of one note is three times as high as another when the first consists of three times the number of vibrations in a second. The vibrations in Germany and England are usually considered as the complete ones—that is, the swing to *and* fro of the parts of the sonorous body. In France, a vibration is half this, or a swinging to *or* fro. The pitch,

in the more limited or technical sense, signifies the arbitrary or conventional relation between the name of a note and the number of vibrations which produce it The pitch now most usually adopted is the French standard pitch, or that of the "normal diapason," which represents the note A in the treble stave, and which consists of 435 complete (English) vibrations per second English concert pitch A consists of a few more vibrations per second The pitch of the same nominal note varies in different countries, and has varied in all countries from year to year before the establishment of the French standard, which promises at last to fix the relation permanently

PITCH CIRCLE In toothed wheels, the circle which would bisect all the teeth When two wheels are in gear, they are so arranged that their pitch circles touch one another (See *Toothed Gear*)

PLANE MIRROR A reflecting surface perfectly plane, used to reflect incident rays of light without affecting their convergence, divergence, or parallelism (See *Mirror*)

PLANE POLARISATION (See *Polarisation Plane*)

PLANET (πλανάομαι, to wander, ἀστὴρ πλανήτης, a wandering star) This name was originally intended to distinguish those celestial bodies which change their place upon the heavens, but the term is now limited by astronomers to those solid and massive orbs which revolve around the sun at different distances, in nearly circular orbits It includes two distinct families—the *major planets*, Mercury, Venus, Mars, Jupiter, Saturn, Uranus, and Neptune (within which family the earth, though not, astronomically speaking, a *planet*, must yet be included, falling into place between Venus and Mars), and the *minor planets* or zone of asteroids revolving between the orbits of Mars and Jupiter The family of major planets may also be itself subdivided conveniently into two portions, the intra asteroidal planets, Mercury, Venus, the Earth, and Mars, and the extra-asteroidal planets, Jupiter, Saturn, Uranus, and Neptune This subdivision is not arbitrary, since the characteristics of the planets travelling within the zone of asteroids differ in the most marked manner from the characteristics of the planets travelling outside that zone

Under various heads will be found a full account of the apparent motions of the planets and the interpretation of those motions, involving the recognition of the planets' real motions (see *Ptolemaic, Tychonic, Copernican, and Newtonian Systems*), the general elements of the planets (see *Elements*), the aspect and physical habitudes of each planet (see *Mercury, Venus, &c*), and other such matters We propose here to give a brief sketch of the relations presented by the planets *inter se*

In taking a general view of the planetary system, we are struck first by the indications of law in the orderly sequence of the planetary distances Near the sun the distances increase slowly, the intervals between orbit and orbit being relatively so small that the whole group of intra asteroidal orbits might be placed between the orbits of Jupiter and Saturn, with a wide interval separating it from either Between the orbits either of Neptune and Uranus, or of Uranus and Saturn, the whole of the asteroidal zone, and the planets circling within it, could in like manner be placed, with a very wide interval of separation on either side In considering the relations of distance, we see farther that the rate of increase of the successive orbit-intervals exhibits indications of a uniform law of progression It was the recognition of these indications which led Kepler, Titius, and Bode to construct that empirical law of association, which commonly bears the name of the last named astronomer (See *Bode's Law*) Although we cannot at present recognise any physical basis for such a law, it must yet not be forgotten that we owe to the attention directed to Bode's law, the discovery of the zone of asteroids, and farther, that though it fails in the case of Neptune, yet neither Adams nor Leverrier would, in all probability, have been willing to undertake the analytical search for this planet had they not been aided by the assurance which the law gave them that the unseen orb lay within certain limits of distance

For our present purpose it is sufficient to describe the order of distances of the planets, as far as Uranus, as such that each is about twice as far beyond the orbit of Mercury as the next inner planet is Neptune on the one side and Mercury on the other, remain thus outside the range of the law The general account of the system is completed by adding that Mercury is about half as far as Venus, and Neptune about half as far again as Uranus from the sun

Next as regards the dimensions of the planets Here it is not so easy to recognise the presence even of an incomplete law The intra asteroidal planets are all small compared with the extra-asteroidal orbs, but within each family there seems wanting all traces of orderly sequence Proceeding from the sun, we find Mercury the least of the planets, then Venus nearly as large as the Earth, then the Earth, and then Mars which, though larger than Mercury, is very much smaller than either Venus or the earth Outside the asteroidal zone, we find, first, the giant planet Jupiter, then, Saturn, very much less, but still far larger than all the other

planets taken together, next, Uranus, which, compared with Saturn, is somewhat as Mercury compared with the earth, then, lastly, Neptune which is larger than Uranus (somewhat as Mars exceeds Mercury) One can recognise no traces of law here

As regards the masses of the planets, the same absence of law is noticed The order of the planets in regard to mass is in fact the same as the order with regard to volume, only the relative range of variation is markedly smaller, on account of the small density of the larger planets.

As regards, again, the nature of the schemes swayed by certain planets, it is difficult to recognise the traces of any law We find all the extra asteroidal planets provided with attendants But Jupiter, though the largest, has not the largest attendant system, being far surpassed in this respect by Saturn As to Uranus and Neptune, it would be difficult to form an exact opinion, since we can hardly imagine that all the satellites attending on these distant worlds have been discovered (See *Satellites*) In the case of the intra asteroidal planets, one only, the earth, has an attendant orb With respect to the planetary rotations, we find some traces of law Each of the extra asteroidal planets would seem, so far as observation has yet gone, to rotate in a period of about 10 hours, while each of the planets within the zone of asteroids probably rotates in about 24 hours But when we consider the direction of the axes of rotation, we find again an utter absence of all apparent law We do not know certainly the inclination of the equators of Venus and Mercury to the orbit planes of these planets, but it is supposed to be considerably greater than the obliquity of the earth's equator, which is about 23½ degrees The equator of Mars has an inclination of about 28 degrees Passing beyond the zone of asteroids, we find the equator of Jupiter inclined little more than 3 degrees; that of Saturn inclined upwards of 26°, that of Uranus (it is supposed) about 75 degrees, and the equator of Neptune so abnormally placed with reference to the direction of his rotation (assumed to correspond to the motion of his satellites), that his inclination may be described as nearly 160 degrees

In considering those relations which belong to the general aspect of the planetary system, we find that beyond the general laws according to which the planets travel in nearly circular orbits, all in the same direction, and nearly in the plane of the ecliptic, there are few traces of orderly arrangement The planet Mercury has the most eccentric orbit and the one which is most inclined to the plane of the ecliptic Venus, on the other hand, while coming next to Mercury in respect of the inclination of her orbit, has the least eccentric orbit of all the primary planets Uranus has an orbit of considerable eccentricity, but very little inclined to the ecliptic, while the path of Neptune is nearly three times as much inclined to the ecliptic, but not nearly so eccentric as that of Uranus The order of the planetary orbits as respects eccentricity is as follows —

	Eccentricity		Eccentricity
Mercury, . .	0 205618	Uranus, . .	0 046578
Mars, . . .	0 093262	The Earth, .	0 016771
Saturn, . . .	0 055996	Neptune, . .	0 008720
Jupiter, . .	0 048239	Venus, . .	6 006833

Whereas as respects inclination the order is—

	Inclination		Inclination
Mercury, . .	7° 0′ 8 2″	Neptune, . .	1° 46′ 59 0″
Venus, . . .	3° 23′ 30 8″	Jupiter, .	1° 18′ 40 3″
Saturn, . .	2° 29′ 28 1″	Uranus, .	0° 46′ 29 9″
Mars, . . .	1° 51′ 5 1″		

It must be remarked, however, that properly speaking the ecliptic is not a suitable plane of reference for the inclinations, however convenient for terrestrial astronomers The true plane of reference is the medial plane of the system, or that plane with reference to which all the orbit planes oscillate The plane of Jupiter lies very near to this plane, and considered with reference to it, the orbit-planes of Mercury and Venus are appreciably less inclined than they appear in the above table

There are few more interesting chapters in the history of astronomy than those which treat of the mathematical relations presented by the planetary eccentricities and inclinations Seeing these elements as we do undergoing gradual processes of increment and decrement, continuing apparently without change for long periods in a definite direction, astronomers were in doubt, until mathematics solved the difficulty, whether the planetary system were in truth stable, or whether mayhap processes might not be in action which would go on with gradually increasing effect until at length the whole system would go to wrack Gradually, however, the progress of analysis revealed the true interpretation of these processes, and showed them to belong not to changes tending continually in one direction, but to oscillatory variations proceeding in orderly

consisting of a thin cord suspended by one end from a fixed point, and having attached to the other end a small weight usually consisting of lead. When a plumb-line is left perfectly free, the weight, being acted on by gravity, causes the cord to take up a position perpendicular to the general direction of the earth's surface. The plumb line, variously modified, is widely used in the arts, to test and determine straight and vertical lines, as well as horizontal lines by applying the fact that the plumb line always makes right angles with the horizontal. Thus, in the mason's level a board is taken with one side well planed, and a perpendicular is raised upon it, called the *square-line*. A plumb-line is suspended from a point in this perpendicular, so that the weight may oscillate in a hollow made in the board. Then, if the surface to be tested is horizontal, the plumb-line will cover the square-line when the instrument is placed upright upon the surface. (See *Gravity*.)

PLUVIOMETER. (*Pluvia*, rain.) See *Rain Gauge*.

PNEUMATICS. Pneumatics is the mechanics of gases. This science is usually understood to embrace aerostatics or the equilibrium of gases, and aerodynamics or the motion of gases.

POINTERS, THE. A name given to the stars α and β in the constellation Ursa Major, because they lie nearly on a great circle through the pole of the heavens.

POINTS, CONSECUTIVE OR CONSEQUENT. See *Consecutive Points*.

POINTS OF THE COMPASS. The card of the mariner's compass is divided into thirty-two equal angles by lines drawn through the centre, and the extremities of the lines are called the *points of the compass*. The division is made in the following way:—Two diameters are drawn at right angles to each other, one of which is called the north and south line, the other the east and west line; and in the common compass, in which the card is attached to the needle, the axis of the needle is parallel to the former of these. At the extremities of it are marked the letters N (north), S (south); and at the extremities of the other line, the letters E (east) and W (west). The right angles formed by these lines are bisected to obtain the next points, and these are named from their positions on the card. Thus, that between N and E is called N E (north east), and the others in a similar way, S E, S W, and N W respectively. Again, eight new lines are drawn to bisect the eight angles, thus making up sixteen of the thirty two points, and the eight new lines are named as follows:—That between N and N E is called N N E (north-north east), that between N E and E is called E N E, and the others E S E, S S E, S S W, W S W, W N W, and N N W, according to their position. Lastly, sixteen more lines are drawn bisecting once more all the angles, and the names of these are distinguished by the characteristic word *by*. The first line on the east side of N is called *north by east* (N by E), the line to the north of N E, N E by N, that to the east of N E, N E. by E, and so on. The list of all the points stands as follows:—

N.	E	S	W
N by E	E by S	S by W	W by N
N N E	E S E	S S W	W N W
N E by N.	S E by E	S W by S.	N W by W.
N E	S E	S W.	N W
N E by E	S E by S.	S W by W.	N W by N
E N E	S S E	W S W	N N W
E by N.	S by E	W. by S.	N by W

The repeating from memory the names of the points is called by sailors "boxing the compass." In naming directions, the angles between the points are very frequently subdivided again by what are called half points and quarter points. Thus, for example, in proceeding from N to N by E, we should have N by ¼ E, N by ½ E, N by ¾ E, N by E, and so on for the rest. Since a circle is divided into 360°, the angle between each point is 11°15′, and the smallest division is thus one quarter of this, or 2° 48′ 45″. The points of the compass are called by sailors *rhumbs*.

POISON. (*Potio*, to drink.) Any substance which rapidly destroys life when taken internally is popularly called a poison; but when a more exact definition is sought, it is not easy to find, for in most cases the distinction between a poison and a harmless, or even a remedial, substance, is simply one of degree. Many poisons, such as strychnine, prussic acid, corrosive sublimate, and arsenic, become valuable remedies when judiciously employed in minute doses. On the other hand, many common medicines, such as morphia, quinine, calomel, and citrate of potash, are poisonous in large doses. The contagia of epidemic diseases, such as cholera, small-pox, and scarlet fever, are supposed to be definite ferments, endowed with the vital power of self-multiplication and propagation. They should therefore be classed amongst poisons of the most virulent and deadly character.

POLAR CLOCK. An instrument constructed by Sir Charles Wheatstone for ascertaining

the hour, by observing the amount of polarisation of the sky It consists of a tube pointing in the direction of the earth's axis, fitted with a double image prism at the lower end as an eye-piece, and a small hole, covered by a thin plate of selenite, at the end which points to the north pole in the sky The double image prism is capable of rotation, and carries an index which points to the hours engraved on a semicircle The plane of polarisation being always 90° from the sun, when the eye-piece is once properly adjusted, and then rotated until the position of *no colour* is gained, the index will point to the right time

POLAR DISTANCE, NORTH The distance of a celestial object from the north pole of the heavens, measured along a great circle passing through the poles It is usually measured through 180°, so that astronomers seldom speak of *south polar distance*

POLARIMETER A polariscope so arranged as to enable the amount and character of polarisation to be measured as well as seen (See *Polariscope, Saccharometer*, and *Right-handed and Left-handed Polarisation*)

POLARIS (The polar star) The star α of the constellation Ursa Minor It is at present quite close to the north pole, and will continue for many centuries to be the polar star of the northern heavens, though after a time precession will remove it from the position it at present holds

POLARISATION BY ABSORPTION We have explained, under the heading *Polarisation of Light*, that when common light passes through a slice of tourmaline, or a crystal of herapathite, the light polarised in one plane is *absorbed*, whilst that polarised in the opposite plane is *transmitted*

POLARISATION BY DOUBLE REFRACTION See *Polarisation Plane*

POLARISATION, CIRCULAR See *Circular Polarisation*

POLARISATION, COLOURED See *Colours produced by Circular Polarisation*

POLARISATION, ELLIPTICAL See *Elliptical Polarisation*

POLARISATION, MAGNETIC See *Circular Polarisation induced by Magnetic Action*

POLARISATION OF HEAT Heat is capable of being polarised in the same manner as light De la Prevostage and Desains have shown (*Annales de Chimie et de Physique*, t 27, p. 109), that when a beam of radiant heat is passed through a rhomb of Iceland spar, it is split up into two equal beams, both of which are polarised, the first in the principal plane, the second in a plane at right angles to it Heat may also be polarised by reflection, and, under certain conditions, by emission, conformably to Arago's discovery that incandescent solids and liquids have the property of emitting light which is more or less polarised Malus, the discoverer of the polarisation of light by reflection, showed that heat is capable of polarisation, and Berard made experiments on the subject as early as 1812 (*Memoires d'Arcueil*, vol iii) Forbes proved that heat passes far more readily through two plates of tourmaline cut parallel to the axis, than when the axes are crossed In the case of light, as is described elsewhere, two parallel plates of tourmaline transmit, while crossed plates entirely stop, an incident beam This is one of the many analogies between radiant heat and light

POLARISATION OF THE SKY The light from a clear sky is polarised, the maximum effect being 90° from the sun, consequently as the position of the sun varies from hour to hour, the plane of maximum polarisation varies also Upon this fact Sir Charles Wheatstone has based his ingenious *Polar Clock*, which see

POLARISATION, PARTIAL If a ray of light falls upon a reflecting surface of glass at any other than the polarising angle, it becomes partially polarised, the amount of polarisation depending upon the nearness of the angle of incidence to the polarising angle. Partially polarised light does not consist of a mixture of fully polarised and unpolarised light, but the whole of it has suffered a change of properties By repeated reflections from a surface at an angle less than the polarising angle, common light gradually passes from partially to completely polarised light

POLARISATION PHOTOMETER Mr Crookes has devised (*Proc Royal Society*, 1869, p 358), a method of measuring the luminous intensities of two sources of light irrespective of their colour, a desideratum which other photometers will not accomplish It is necessary that neither light should be at all polarised, and the method then becomes susceptible of very great accuracy It is impossible to describe the instrument without drawings, but the principle is as follows —Each beam of light is split into two, polarised in opposite directions (say vertically and horizontally), by means of a double image prism The vertically polarised beam from one of the lights is then superposed on the horizontally polarised beam from the other light If the two sources of light were equal in intensity, their respective halves must also be equal, and being equal in intensity and of opposite polarisations, their superposition must reproduce a beam of common light, polarisation being neutralised There will therefore be no free polarised light in this compound beam. If, however, the two lights are unequal, the polarisation of the

stronger will overpower the opposite polarisation of the weaker, and the problem then consists simply in measuring the amount of polarisation present, or, more simply, in altering the relative distances of the two lights from the photometer until free polarisation vanishes. The standard light devised by Mr Crookes for use with this instrument is obtained from a definite mixture of absolute alcohol and pure benzol, burnt in a specially constructed lamp, having a platinum wick.

POLARISATION PLANE. A ray of *ordinary* light is supposed to be caused by vibrations of a highly attenuated medium, occurring in all directions across the direction of the ray, but a ray of *polarised* light is caused by these vibrations occurring in one plane only. Certain crystals (Iceland spar, for instance), possess the property of double refraction, that is to say, a ray of common light passing through them is divided into two polarised rays, which take slightly different directions, the plane of polarisation (or vibration) of one ray being at right angles to that of the plane of polarisation of the other ray. One ray suffers refraction, according to the ordinary law for transparent bodies, and this is called the *ordinary ray*, whilst the other, called the *extraordinary ray*, is refracted according to a new law. The ordinary and the extraordinary rays emerge from a prism of Iceland spar parallel to each other, and to the original direction of the incident ray. By recombining the two oppositely polarised rays common light is reproduced. If common light is compared to a cylindrical body, such as a round ruler, polarised light may be compared to a flat ribbon. In the case of Iceland spar both polarised rays are transmitted, but by cutting and recementing the halves together in a particular manner, the extraordinary ray is totally reflected, so that it passes out of the field of view, whilst the ordinary ray only is transmitted. This arrangement is called the *Nicol prism* (which see.) This is called plane polarisation by double refraction. Some crystals possess the property of transmitting only one polarised ray. The tourmaline and crystals of iodo sulphate of quinine or herapathite are of this character, they may be compared to a grating of narrow parallel bars, allowing the passage of only those vibrations which are parallel to the direction of the bars. From its property a tourmaline (and also a *Nicol prism*) is called a *polariser*, and if light which has passed through a polariser is received upon another polariser in the same direction as the former, it will continue to be transmitted, but if the second polariser is at right angles to the first, the ray will be stopped by it. For instance, a flat ruler will pass through any number of gratings parallel to its plane, but will be stopped by one at right angles to it. Light may also be polarised by reflection from a polished surface. The angle at which the light must be incident, so as to obtain the maximum polarising effect, depends upon the refractive index of the reflecting body, the law being that the polarising angle is the complement of the angle of refraction. The oppositely polarised ray passes through the glass, and is said to be polarised by refraction. The rays of polarised light are capable of interfering and producing colour like those of common light. The phenomena of coloured polarisation are amongst the most gorgeous in the whole domain of optics. (See *Colours produced by Polarisation*.)

POLARISCOPE. An instrument for showing the phenomena of polarised light. It consists essentially of a polariser and an analyser, with an arrangement between the two for supporting the object under examination, whether it be a selenite film, a slice of a crystal, or a piece of unannealed glass. The polariser for large objects is usually a plate of black glass fixed so as to reflect light into the instrument at the proper polarising angle, but for small objects it may be a Nicol prism, a tourmaline, or a crystal of herapathite. The analyser which comes next to the eye may also be either a tourmaline, herapathite, or Nicol prism.

POLARISED LIGHT. Light which has had the property of polarisation conferred upon it, either by reflection, refraction, or absorption. It may be either plane, circular, or elliptical polarised light. (See *Polarisation, Plane*.)

POLARISER. A reflecting plate or transparent crystal, by means of which common light is converted into polarised light. (See *Polariscope*.)

POLARISING ANGLE. The polarising angle of a transparent substance may be ascertained by Sir David Brewster's law, that "the index of refraction is the tangent of the angle of polarisation." The maximum polarising angles for several substances are as follows:—

Water, . . .	53° 11′
Glass, . . .	56° 45′
Rock crystal, . .	56° 58′
Iceland spar, . .	58° 51′
Diamond, . . .	68° 1′

The following table shows the number of reflections from a surface of glass required to completely polarise light at angles above or below the maximum polarising angle. (See Brewster's Optics, p. 173.)

Below the polarising angle		Above the polarising angle	
No of Reflections	Angle at which the light is polarised	No of Reflections	Angle at which the light is polarised
1	50°45′	1	56°45′
2	50 26	2	62 30
3	46 30	3	65 33
4	43 51	4	67 33
5	41 43	5	69 1
6	40 0	6	70 9
7	38 33	7	71 5
8	37 20	8	71 51

POLARISING MICROSCOPE In the best forms of compound microscope, a *polariser*, generally a Nicol's prism, is attached below the stage, and an analyser, (another Nicol's prism,) is fixed above the object glass, in this manner forming a polariscope in which any crystal or other transparent object on the stage may be examined (See *Polariscope*)

POLE (πόλος, a pivot or axis) In astronomy the name given to each of the two points in which the imaginary axis of the celestial rotation, or the axis of the earth, would, if produced, meet the sphere of the heavens The term is also used in astronomy, as in spherical trigonometry, &c, to indicate the poles of any great circle of the sphere, in other words, the extremities of the line drawn at right angles to the plane of the circle through its centre to meet the sphere In this sense astronomers speak of the poles of the ecliptic, and so on

POLE, MAGNETIC See *Magnetic Pole*

POLEMOSCOPE (πολεμος, war, and σκοπεω, to view) A tube bent twice at right angles with oblique reflectors at the angles, so arranged that an object can be examined without the observer being seen It is useful in war for getting a knowledge of the enemy's movements, without causing the observer to be exposed to danger

POLE, NEGATIVE, OF A GALVANIC BATTERY The extremity of the battery which becomes negatively electrified before the two extremities are joined by a conductor (See *Battery, Galvanic*, and *Pole, Positive*)

POLE, POSITIVE, OF A GALVANIC BATTERY, is the extremity of the battery which becomes positively electrified before the two extremities are joined by a conductor (See *Battery, Galvanic*) The current, according to our conventional way of speaking, passes through the liquid towards the positive pole, and through the interpolar conductors from the positive pole

POLE, UNIT See *Unit Pole*

POLLUX The star β of the constellation Gemini. It is somewhat brighter than the other twin star Castor It is multiple

POLY-CHROISM See *Dichroism*

POLYGON OF FORCES (πολύγωνος, many-angled, and consequently, many sided, γώνος, γώνια, an angle) A principle, said to have been discovered by Leibnitz, by which we may find the resultant of any number of forces (in one plane) acting upon a point It may be thus stated —If any number of forces act upon a point, and a polygon be described, having the line representing one of the forces for one of its sides, and the remaining sides successively parallel and equal to the lines representing the other forces, the line which completes the polygon will represent the resultant of the forces The proposition is proved by finding the resultant of each pair of forces by the parallelogram of forces, and then further compounding these resultants The single resultant which is finally obtained is found geometrically to coincide with the side completing the polygon From this it follows that when a number of forces acting upon a particle can be represented in magnitude and direction by the sides of a closed polygon taken in order, the forces are in equilibrium (See *Parallelogram of Forces, Triangle of Forces*)

POLYZONAL LENS Sir David Brewster constructed a large convex lens of flint glass three feet in diameter, built up of many zones and segments, the pieces being each ground to the proper curvature, and afterwards cemented together Lenses of this kind are now introduced into lighthouses, they have the advantage of being constructed of any diameter, and by curving the different surfaces so as to make the foci of each zone coincide, the spherical aberration may be practically corrected Lenses of this kind would not be perfect enough for employment in cases where the formation and examination of an image is requisite.

PONTOONS (Fr *ponton*, L *pons*, a bridge) Portable floating vessels for making military bridges (See *Bridges*)

POROSITY (Lat *porositas*, from Gr πόρος, a passage) A term used to describe the fact that in all matter with which we are acquainted the constituent particles are not uniformly and completely contiguous to one another, but are separated by intervening spaces or pores The density of a body bears an inverse ratio to its porosity (see *Density*), thus gold and platinum, being of great density, are much less porous than cork, or than any liquid or gas It was at one time thought that the heavy metals were so dense as to possess no pores whatever, and to solve this question an experiment was performed at Florence in 1661 upon gold, one of the heaviest substances A hollow sphere of gold was filled with water, and securely closed It was then subjected to a pressure so great as to alter the form of the sphere Now, it may be proved by geometry that a given surface encloses the greatest possible space when it is in the form of a sphere When the experiment was tried, therefore, it was expected that either the liquid would be compressed or that the vessel would burst But a slight compression of the liquid occurred, the porosity of the gold was proved by the appearance of the water like dew on the exterior of the sphere, no bursting or other injury to the integrity of the globe taking place

The pores of bodies may be filled by other substances whose particles are smaller than the pores Thus, in filtration we separate from liquids various solid particles which are too large to enter or pass through the pores of the filtering material, such as paper, charcoal, &c, while the liquid will enter and pass through them When the pores are not filled with other substances they are usually filled with air When sugar is dissolved in water the air is seen to rise to the surface of the liquid in bubbles, and very frequently under the receiver of an air-pump substances placed in water may be seen to give up the air which was contained in their pores, as the receiver gradually becomes exhausted

The porosity of liquids is shown by an experiment such as the following A glass instrument is taken, consisting of two connected bulbs and a tube, having a very narrow neck, so that a small decrease in bulk may be noted A quantity of water is placed within the instrument, and it is then filled up with spirit of wine, after agitation, an empty space will be seen at the top of the neck, showing that the particles are closer together than they had previously been

Many metals become more dense by hammering, and all metals decrease in volume as they are rendered colder, so that the particles cannot be in complete contact The passage of gases through the pores of metallic septa has recently afforded a fruitful field for investigation (See *Diffusion of Gases*, and the papers of Deville and Troost, Phil Mag IV, xxvi 336, and Graham, Phil Trans, 1866) Graham's conclusions as regards degrees of porosity are that "there appear to be (1) pores through which gases pass under pressure, or by capillary transpiration, as in dry wood and many minerals, (2) pores through which the gases do not pass under pressure, but pass by their proper molecular movement of diffusion, as in artificial graphite, and (3) pores through which gases pass neither by capillary transpiration, nor by their proper diffusive movement, but only after liquefaction, such as the pores of wrought metals, and the finest pores of graphite" (See *Density, Compressibility, Capillarity*)

POSITION CIRCLE A polished metal circle graduated from 0° to 360°, and sometimes attached to a micrometer eye-piece, the equatorial mounting of a telescope, &c, and generally wherever any portion of an instrument has to be rotated, and the angle through which it moves measured Applied to an equatorial telescope the position circle on the polar axis is called the *right ascension circle* or *hour circle*, and the one attached to the telescope is called the *declination circle* These circles are sometimes many feet in diameter, and are subdivided to minutes, and with *Verniers* may be read to seconds, and even less (See *Hour Circle, Declination Circle, Vernier*)

POSITIVE AND NEGATIVE AXIS OF CRYSTALS Common light falling on a doubly-refracting crystal in any direction except along the axis, is split up into two polarised rays, the ordinary and the extraordinary ray, which advance with unequal degrees of velocity, and are refracted differently When the extraordinary ray advances more rapidly, it is refracted *towards* the axis, and the crystal is said to have a positive axis, but when the extraordinary ray advances least rapidly, it is refracted *from* the axis, and the crystal is said to have a negative axis Iceland spar and arragonite have negative axes, quartz and selenite have positive axes (See *Crystals, Optic Axes of, Crystals, Double Refraction of*)

POSITIVE EYE-PIECE This eye-piece is generally used in telescopes and microscopes, where it is desired to use it in conjunction with a micrometer. It consists of two plano convex lenses, the convex sides turned inwards, and their focal lengths equal They are placed at such a distance apart that the equivalent focus falls a little in advance of the field lens, so that the threads of the micrometer can be accurately focussed without particles of dust, &c on the field-glass being visible. (See *Eye-piece, Negative Eye-piece, Micrometer Eye-piece*)

POTASH See *Potassium*

POTASSIUM A metallic element, compounds of which are very widely diffused It was first obtained in the metallic state by Davy in 1807 by the electrolysis of its hydrated oxide It is a bluish white metal of a pasty consistency, and easily welded when two clean surfaces are kneaded together between the fingers Specific gravity 0 865, symbol K, from Kalium, a name derived from the Arabic Kali, atomic weight 39 1 It melts at 62 5° C (144 5° F), and at a red heat distils, forming a beautiful green vapour The affinity of potassium for oxygen is very great A freshly cut surface instantly tarnishes in the air, and when a small piece of the metal is thrown into water it decomposes it, liberating the hydrogen, and evolving so much heat as to cause the ignition of the gas, which burns with a violet flame, whilst a globule of the melted metal floats on the surface of the water, and the remaining globule of red-hot potash finally disappears with explosion as it unites with the water Heated with bodies containing oxygen, potassium quickly decomposes them The metal can only be preserved by covering it with mineral naphtha—a hydro carbon free from oxygen, and sufficiently light to allow the potassium to sink in it Potassium is obtained by heating a mixture of carbonate of potassium, carbonate of calcium, and carbon, to whiteness in an iron tube arranged as a retort The potassium is set free by the carbon, which takes its oxygen, forming carbonic oxide, and distils over, and is received in vessels containing naphtha The compounds of potassium are numerous, and many of them important The principal ones are as follows —

Potash The *hydrated oxide* or *hydrate of potassium*, frequently called *caustic potash.* Symbol $K_2O\ H_2O$, or KHO, specific gravity, 2 1 It is white and crystalline, melting below a red heat to a clear liquid, and volatilising at a higher temperature Exposed to the air it rapidly absorbs water, and becomes carbonated It is very soluble in water and alcohol, and its solution has a powerful corroding action on animal and vegetable substances, on which account it is sometimes used as a caustic in surgery Its solution is intensely alkaline, it turns litmus-paper blue, and turmeric paper brown It neutralises all acids, forming, for the most part, well defined and crystalline compounds (For a description of the most important of these see the names of the acids) It is of great value in the laboratory as a reagent, both on account of its powerful affinity, in the liquid and solid state, for carbonic acid, and also in solution as a precipitant for heavy metallic oxides from their salts

Chloride of Potassium (KCl) is found native at Stassfurth, and is known under the mineralogical name of *Sylvine* It also occurs in sea water and brine springs It crystallises in cubes, which dissolve easily in water, but are very slightly soluble in alcohol The crystals are permanent in the air, taste somewhat like common salt, and when heated decrepitate, and melt at a dull red heat, volatilising at a higher temperature

Bromide of Potassium (KBr) forms brilliant cubical crystals, easily soluble in water, decrepitating and melting below redness

Iodide of Potassium (KI) This salt forms cubical crystals, usually white and opaque. They are permanent in the air, and melt below a red heat They are very soluble in water, and tolerably so in alcohol A solution of iodide of potassium dissolves iodine, forming a deep brown solution

Fluoride of Potassium (KF) This is a deliquescent crystalline compound, very soluble in water, forming a solution having an alkaline reaction and sharp taste It forms double salts with other fluorides

Cyanide of Potassium (KCy) A compound of potassium with the compound radical cyanogen (See *Cyanogen*) In the pure state it forms cubical crystals, but, as usually met with, it is a hard, white, opaque fused mass, very soluble in water, and deliquescing in the air In this state it contains also cyanate and carbonate It is much employed in photography

POTENTIAL, ELECTRIC A term applied by George Green, of Nottingham, and much used with respect to the mathematical theory of electricity The conception of the potential is, however, by no means confined in its connection to electricity, it belongs, in fact, to the theory of attraction generally

Sir William Thomson thus defines electric potential (British Association Report, 1852, Phil Mag, 1853) —"The potential at any point in the neighbourhood of or within an electrified body, is the quantity of work that would be required to bring a unit of positive electricity from an infinite distance to that point if the given distribution of electricity remained unaltered" He also speaks of the difference of electric potential between any two points as the quantity of work required to move a unit of electricity from one point to the other The difference of potential between any two points is the electromotive force between them A difference of electric potential between two points tends to produce a transference of electricity from one of them to the other.

Friction of various bodies, the motion of magnets, chemical action, &c., alter the potential of

certain points, or maintain a difference of potentials between them, which gives rise to an electric current

The difference of electric potential between two points is unity, if a unit of mechanical work is spent in transferring unit quantity of electricity from one of the points to the other

When, instead of a difference of electric potential between two points, the *potential of a point* simply is spoken of, the difference of potential between that point and the earth is referred to, or, in fact, the electromotive force between that point and the earth

A surface at every point of which the potential has the same value is called an *equipotential surface* On such a surface the attraction is at each point normal to the tangent plane at the point, for there is no change of potential from point to point in any direction along it, and therefore there is no force in any such direction In any space the *lines of force* obviously cut all equipotential surfaces normally

When a current is passing through a circuit the potential is different at every point along the circuit The difference from point to point depends upon the resistance between the points and the electromotive force of the source of electricity

With these few but important definitions and explanations, we must refer the reader to Thomson and Tait's Treatise on Natural Philosophy, and to the papers of Thomson, British Association Report, 1852, Philosophical Magazine, 1853, Proceedings of the Royal Society, 1860, Phil Mag, 1860, where full information, with the statement and proof of various important propositions, will be found

POWER In mechanics, any force which, applied to a machine, tends to produce motion The mechanical powers are the six simple machines, namely, the *lever*, the *wheel and axle*, the *pulley*, the *inclined plane*, the *screw*, and the *wedge*

PRÆSEPE (A beehive) In astronomy, a fine cluster of stars in the constellation Cancer one of the few known to ancient astronomers

PRASE See *Quartz*

PRECESSION OF THE EQUINOXES A gradual change in the position of the nodes of the earth's equator on the ecliptic Its nature is such that the nodes of the celestial equator on the ecliptic—in other words, the first points of Aries and Libra are continually travelling along the ecliptic in a direction contrary to the order of the signs The mean rate of the motion is such that a complete revolution of the nodes is accomplished in 25,866 years Thus the mean annual amount of precession is 50″ 10, and the nodes shift one degree in 71 6 years

The precession of the equinoxes was discovered by Hipparchus (See *Astronomy*)

The physical cause of precession is the action of the sun and moon, and, in a minor degree of the planets, upon the protuberant equatorial portion of the earth's spheroidal mass If we consider any particle of this protuberant mass, we see that, if free, it would travel around the earth and that its orbit would be liable to changes of position resembling in their general character those which affect the moon's orbit Now, since this is true of every particle, it is clear that there is a general tendency in the protuberant mass to shift as the moon's orbit does, that is on the whole, retrogressively, and at such a rate that a complete revolution of the nodes of the equator plane would be effected within a moderate number of years But this tendency is resisted by the cohesion which binds every particle of the protuberant mass to the terrestrial globe This globe may be regarded as a mass which these particles are severally endeavouring to shift in such sort that the nodes of its equator plane shall move retrogressively round the plane of the ecliptic Now, this action of the particles *does* prevail to shift the earth's mass in this way, but the rate at which the change takes place is very much slower than that at which the orbit plane of any particle's motion would shift The actual rate of change will depend on the forces at work to produce the change, and on the mass of the earth The sun, of course exerts an influence here precisely resembling that which he exerts on the moon's orbit But the moon also holds a position with respect to each of the imaginary particles, corresponding to that which the sun holds with respect to the moon Each particle travels round the earth in a plane not coinciding with the plane of the moon's orbit, and therefore the moon at all times except when on the plane of the equator, tends to modify the position of each particle's plane of motion precisely as the sun modifies the position of the moon's

Here, then, we have a general explanation of what is termed the luni-solar precession of the equinoxes But the lunar precession is affected by a peculiarity which still remains to be accounted for We have seen that the moon's action depends on the inclination of her orbit to the plane of the earth's equator This inclination is subject to an oscillatory change whose period is about nineteen years Hence also there arises an oscillatory variation in the rate of precession, the nodes retrograding less swiftly than they otherwise would when the moon's inclination is less than the average, and more swiftly when the moon's inclination is greater than the average. But further, the inclination of the earth's equator-plane to the ecliptic is modified

y the moon's action, precisely as the inclination of the moon's plane to the ecliptic is modified y the sun's action This change is, of course, also oscillatory, and has the same period as the scillatory change in the rate of precession The combination of these two oscillations causes nutational motion of the earth's axis in an elliptic cone round the constantly retrograding ean position of the axis, the extent and figure of the cone's elliptic section being such as is escribed under the head *Nutation* (*q v*) Laplace, *Mécanique Céleste*

PRECIPITATE A name applied in chemistry to a solid, which is separated from a solu ion in the amorphous or crystalline form, by the addition of a reagent or exposure to heat r light The process of precipitation is largely used in analytical chemistry and in manufactur ng operations, as a means of separating or purifying chemical compounds.

PREDICTIONS, WEATHER See *Weather*

PRESSURE In statics, it is synonymous with force Hence pressure is a force counter- cted by another force, so that no motion is produced When a body is laid on a horizontal able, its weight will be counteracted by the resistance of the table, this resistance is a pres- ure A pressure tending to compress the body on which it acts is termed a *thrust* when ap- lied from without, and a *reaction* when called into existence by a *thrust* When a body is acted n by two equal and opposite pressures which tend to produce elongation, each is termed a *train* or *tension*, the former term being used when the body is inflexible, the latter when it is lexible Thus we speak of the *strain* of a tie beam and the *tension* of a cord For parallelo- ram of pressures, see *Parallelogram of Forces*

PRESSURE OF LIQUIDS ON THE BOTTOM OF VESSELS Since (*Level Surface f Liquids*) whatever be the size or shape of the two communicating vessels, the liquid in them s at rest when the level of each is the same, we may suppose any surface in the liquid at rest o be the field where two equal and opposite forces counterbalance one another Thus, let a rumpet shaped tube be bent in the middle into a U form The surface of the liquid which the ube holds will be of the same horizontal height in both limbs Since there is equilibrium hroughout, there must be equilibrium on every plane surface of the liquid, consequently on the ertical plane section of the bend of the tube On the one side of this plane we have a liquid olumn, tapering as we ascend, on the other an expanding column of equal height Conse- quently the pressure exerted on this intermediate plane does not depend upon the total quan- ity of liquid above it, but upon its depth below the liquid surface Conceive the tube to be livided in the middle, and bottoms to be supplied at both ends The resistances of these bottoms would be equal to the pressures upon them, and therefore equal to one another, since the latter are so Hence the pressure on the bottom of a vessel containing a liquid varies with the eight of the liquid above it It also, of course, varies with the size of the base, because, tak- ng equal and similar vessels side by side, the pressure on the two bottoms together is twice that n one, and the same must be true when the two neighbouring vessels are joined into one, aving therefore a base of double size Consequently, in general terms, the pressure on the ottom of a vessel containing a liquid is equal to the weight of a vertical cylindrical column of water, whose base is the bottom, and whose height is the depth of the liquid This pressure lso, of course, varies as the density of the liquid A simple experimental proof of this prin- iple may be given by taking a cylinder, open at both ends, placing a disc of wood on the lower nd, fastening a string to the centre of the wooden disc, passing the string up along the axis of he cylinder, and hanging the whole up by the string Whatever quantity of water may be poured nto the cylinder, no leakage occurs, because, though the weight of the contained water strives to push off the disc, the tension of the string increases *pari passu*, so that equilibrium is maintained.

PRESSURE THROUGH LIQUIDS—PASCAL'S LAW The parts of a rigid body or olid are so bound together by cohesion that a pressure acting on one point in any direction will tend to move the whole of the solid in that direction Other mechanical forces, such as riction, inertia, &c, may modify the direction in which the parts of the body may move, but unless rupture of the body take place, the relative positions of the parts to one another remain unchanged This is strictly true of only absolutely rigid solids In elastic solids it is true that such relative positions may alter, but still, as far as is known, neighbouring particles remain neighbours, whatever modification of form the solid may undergo when submitted to pressure The essential mechanical difference between solids and liquids is, that while in solids the cohe- sion is sufficient to maintain the relative position or neighbourhood of the parts, that is, the approximate shape of the solid, the cohesion of liquids is so very much less, that the slightest mechanical force sets in motion that portion of the liquid mass on which it acts, and such a portion moves with but little resistance among the neighbouring parts In other words, there is with liquids but little effort to maintain local relative position When a solid which is in- soluble in a liquid is plunged into a quantity of that liquid, the (upper) surface of which is exposed to the air, the liquid must be displaced. (See *Displacement*, also *Wave*) The dis-

placed portion pushes against the neighbouring parts, and so on, the result being a lifting of the surface If a piston be driven into a cylinder communicating with a vessel of liquid—both vessel and cylinder being replete with liquid—it is found that every equal area of the vessel's surface is pressed outwards with equal force, and that every portion whose area is equal to the area of the piston is pressed by a force equal to the pressure applied to the piston Hence is deduced the law known as *Pascal's law*, that "when any portion of the surface of a confined liquid is pressed by any force, every other portion of the surface of the confining vessel equal in area to the first portion is pressed by an equal force" In other words, liquids transmit pressure equally in all directions The same law is equally true of all gases, and therefore of fluids generally

PRIMARY AND SECONDARY RAINBOW See *Rainbow*.

PRIMARY COIL See *Coil, Primary*

PRIME CONDUCTOR OF AN ELECTRIC MACHINE See *Conductor, Prime*

PRIME, VERTICAL In astronomy, a great circle passing through the east and west points of the horizon and the zenith

PRIMUM MOBILE (Lat) A term belonging to the *Ptolemaic System* (*q v*)

PRINCE RUPERT'S DROPS When substances possessing a high temperature are suddenly cooled, their particles are in a state of strain If glass is melted and poured into water, the external surface is instantly solidified and cooled, while the internal portions cool more slowly, hence arises a difference of equilibrium in regard to the molecular force of the surface particles and those in the interior, in fact, the exterior surface which cooled first has to bear the strain due to the contraction of the inner particles, and this it does from the perfection of its form, which is usually that of an ellipsoid prolonged in the direction of its major axis at one end into a lengthy tail gradually lessening in thickness until it becomes pointed On account of this tear-like appearance, such pieces of unannealed glass are called *Larmes Bataviques* by the French, in this country they are sometimes called *Dutch Tears*, but more generally *Prince Rupert's Drops*, from their discoverer Now, when there is a break of continuity at any point of the surface, as by scratching it with a diamond, or breaking off the tip of the tail, the whole mass is instantly pulverised, the strain has suddenly ceased, the strained molecules are released, and equilibrium is restored The particles have been existing in a state of molecular potential energy, hence we should expect that when it leaves this condition on the removal of the restraining influence, heat would result, and that this is the case has been proved within the last few months The *Bologna Flask* illustrates in like manner the condition produced in certain solids by sudden cooling It consists of a very thick flask of blown glass, which has been quickly cooled, when the surface is ruptured, as by shaking a little piece of flint in the flask until a slight scratch is produced, the bottom instantly falls out The explanation which applies to the breaking of Prince Rupert's Drops is obviously equally applicable to the Bologna Flask It results from the above facts that fragile articles of brittle material must be very slowly cooled if they are to be submitted to changes of temperature A tumbler of badly annealed glass cracks when hot water is poured into it, because it has been too quickly cooled, and the hot water, in expanding the interior surface, produces a strain upon the contiguous particles which they cannot bear without rupture When glass is properly annealed, it is placed in a furnace, which passes in various positions of its length from nearly a red heat to a heat below that of boiling water, and by slowly passing the glass from the hot to the cool end of the furnace, it becomes so well annealed that sudden changes of temperature can be readily withstood without fracture

PRINCIPAL CURRENT See *Derived Currents*.

PRINCIPAL FOCUS See *Focus*

PRINCIPIA The name of the immortal work in which Newton presented and established the theory of gravitation

PRISM (πρισμα, from πριζω, to saw) In optics a prism is a triangular shaped piece of glass or other transparent medium with polished surfaces The section may be either a right angle, an equilateral, or an isosceles triangle The *equilateral* and *isosceles prisms* are employed for effecting the prismatic decomposition of light When a ray of light falls obliquely upon one of its refracting surfaces, it passes through and emerges at the opposite face, suffering at its ingress and egress two refractions in the same direction, whereby, unless the light be homogeneous, the ray is spread out into its component colours, forming a spectrum The *right angle prism* (which see), is used as a reflector Besides the above, there are the *prismatic lenses, double image prism, Nicol's prism, Wenham's prism, compound prism, achromatic prism, direct vision prism, variable prism, erecting prism, liquid prism, disulphide of carbon prism, quartz* or *rock crystal prism*, for particulars of each of which see their respective headings

PRISMATIC DECOMPOSITION OF LIGHT. See *Dispersion*.

PRISM, DIRECT VISION In the article "*Achromatism*," it has been shown how it is possible to produce refraction without dispersion by using two kinds of glass, which, for the same amount of dispersion, will refract differently, and thus neutralising their dispersion, and making use of the balance of refraction A system of direct vision prisms is based on the converse principle to this The flint and crown glass prisms are so cut that their mean refractions shall be equal, and therefore neutralise each other The ray of light consequently emerges in the same direction as it enters, as, however, for equal amounts of refraction, the dispersive powers of flint and crown glass are different, these will not neutralise each other, but will leave an excess of dispersion Direct vision prisms are very convenient, but owing to the thickness of glass, and the many surfaces through which the light has to pass in order to produce any considerable amount of dispersion, their performance is inferior to that of good glass prisms of the usual construction

PRISM, DOUBLE IMAGE A double image prism may be made of any doubly refracting crystal, but, in practice, calc or Iceland spar is always employed, except in special cases, where it is advisable to employ quartz Under the heading "*Polarisation Plane*," the cause of the double image given by calcspar is explained To form a double image prism of calcspar the crystal is cut so as to produce the greatest possible divergence between the ordinary and the extraordinary rays, and it is then rendered achromatic by a prism of glass cemented to it. To increase the separation the glass is sometimes replaced by another prism of calcspar

PRISM TELESCOPE An instrument by which magnifying power may be obtained by the combination of four prisms of the same glass (See *Brewster's Optics*, p 363)

PRISM, NICOL'S See *Nicol's Prism*

PRISM, WENHAM'S See *Wenham's Prism*

PRISMATIC LENS Light incident upon a right angle prism perpendicularly to one of its faces suffers total reflection (See *Reflection of Light, Total*, and *Right Angle Prism*) The entrant, or emergent side, or both, may be ground to a concave or convex spherical surface, and the prism then acts in all respects as a lens, having similar surfaces, with the addition of bending the ray at right angles, and reversing its sides In this manner we can have a *double-convex prism, plano convex prism, double concave prism, plano concave prism, meniscus prism*, and *concavo-convex prism*, and by cementing to one or both of these curved surfaces an appropriate lens of another kind of glass, the prismatic lens may be achromatised

PROCYON (προ and κύων, a dog, the star that rises before the dog star) The star α of the constellation Canis Minor

PROJECTILES (*Projicio*, to throw forward, set in motion) When a body is thrown vertically upwards it moves in a straight line, and returns to the place from which it started. When, however, the direction of projection makes an angle with the vertical, the body describes a curve Suppose the direction of projection to be horizontal, in order to find the position of the body at any time, we must apply the second law of motion Now, the force of gravity will draw it as far from the horizontal line of projection in a given time when it starts with a certain velocity, as when it starts from rest If, therefore, we mark off on a horizontal line the positions which the body would occupy at successive intervals of time if gravity did not act upon it, and from each of these points draw a vertical line equal to the space through which a body would fall freely up to the instant marked by the points, and join the extremities of all the lines thus drawn, we obtain the path of the projectile This construction is precisely that required to draw the curve called in geometry a parabola Hence, if the resistance of the air be not taken into account, the path of a projectile is a parabola (See *Laws of Motion*)

To determine the greatest height to which a projectile will rise, the velocity at starting is resolved into two components, one vertical, the other horizontal, and the greatest height is found by dividing the square of the vertical velocity by twice the acceleration of gravity The range on a horizontal plane is found by dividing twice the product of the vertical and horizontal velocities by the acceleration of gravity The range of a projectile will be greatest when the angle of projection is 45°

In this theory the resistance of the air has not been taken into account, and this resistance affects the motion so materially as to render the parabolic theory nearly useless in practice The path inclines to the earth more rapidly than is the case with a parabola, hence the range is much less For example, when the velocity is about 2000 feet, the resistance of the air is 100 times the weight of the ball, and the greatest range, which, according to theory, should be 23 miles, is less than 1 mile (See *Gunnery*)

PROGRESSIVE VIBRATIONS See *Permanent Vibrations*, and *Waves*

PROMINENCES, COLOURED In total eclipses of the sun, strange projections, tinted of a delicate rose red, make their appearance Some of them extend as far as 80,000 miles from the surface of the sun. During the total eclipse of August 1869, it was discovered that

these objects consist of glowing gas, principally hydrogen Janssen, one of the observers of that eclipse, discovered, only one day after, that the spectra of objects could be seen when the sun is not eclipsed Two months later, Mr Lockyer independently made the same discovery It is even possible that, independently of the eclipse observations of 1868, Mr Lockyer might have succeeded in discovering the prominence spectra, as he had suggested the possibility of their being seen without an eclipse Dr Huggins soon after made a more interesting and important discovery, showing that the prominences themselves (and not their bright lines only) can be rendered visible with the spectroscope (having an open slit)

PROOF PLANE (French, *Plan d'épreuve*) An instrument invented and used by Coulomb in his experimental researches on the distribution of electricity It consists of a very small disc (a quarter or half-an inch in diameter) of thin metal or gilt paper, to one side of which is attached, perpendicular to its plane, a fine stem or handle of glass or shell lac To make use of the proof plane, it is held by the insulating handle and applied to the surface to be tested, and when it is completely in contact with the surface it forms, as it were, a part of it, and the electricity spreads over it When it is carried away to the torsion balance or other testing instrument, it carries away its electricity with it

Coulomb in his sixth memoir on electricity (*Histoire de l'Académie*, 1788), gives the theory of the proof plane, in which he shows that the small conducting disc carries away with it as much electricity as lies on an element of the surface to which it is applied equal in area to the superficial area of the disc It is to be remarked, however, that the actual quantity carried away is only one-half of this, in fact it is the quantity which lies on *one* of the faces of the disc when it is placed in contact with the conducting surface

PROPAGATION OF SOUND The simplest instance of the formation of a sound is the sudden expansion of a little spherical mass of solid matter in the midst of a mass of air at rest The air will be thrust away from the centre by the expanding surface, and driven into the space occupied by the neighbouring air, before the latter can be set in motion There will, therefore, be a condensation of the air around the spherical surface But this state cannot be permanent The spherical shell of compressed air which clothes the solid exerts its increased elastic force or tension upon the neighbouring particles, forcing them together also into a shell of compression But, in doing this, the momentum acquired by the particles of the first compressed shell causes them to separate farther than they were originally, so that, immediately behind (towards the centre) of the second compressed shell of air there is a shell of rarefied air clothing the solid The second shell of compressed air exerts its elastic force to compress the air in both directions, rarefying itself by its momentum, and so on It follows that the effect will be the propagation of one chief shell of compression followed by a chief wave of rarefaction of much less intensity, concentric with one another and with the solid sphere These will be followed by very much more feeble similar conditions of compression and rarefaction, due to the air's momentum It is, in fact, only when such original expansion is extremely sudden and violent, as when a mass of fulminating powder explodes, that we hear more than a single sound And we may generally consider the state of the air brought about by a single expansion of a solid body in it, as consisting of an ever expanding shell of the condition of compression

If the solid body, after expansion, immediately commences to contract, and contracts to the same extent as it expanded, there will be formed around it an envelope of rarefaction, and, as in the case of the envelope of compression, this state will travel as an expanding shell of rarefaction immediately following the state of compression If now the solid sphere expands and contracts at regular intervals and continually, a series of spherical shells of compression will follow one another at regular distances apart, and alternating with these will be spherical shells of rarefaction also at regular intervals So that if we take a plane elastic membrane at any distance from the original sphere, and parallel to the nearest tangent plane of the sphere, we shall find this membrane to be subjected to a series of alternate pushings and pullings, taking place as it is subjected in succession to the alternate conditions of the travelling regions of compression and rarefaction, it will vibrate "synchronously" with the expanding and contracting sphere And so a succession of sounds are propagated through the air

That some elastic medium is necessary for the propagation of sound, that is, some medium which recovers from a state of abnormal compression and communicates its condition to the neighbouring portions, is shown by supporting an alarum clock by means of non-elastic thread under the receiver of an air pump and withdrawing all the air (See *Air pump*) The bell which is struck has now no medium in which to establish vibrations, and consequently no sound is heard On admitting air, the shells of expansion and contraction are established, and are communicated to the glass of the receiver, they are transmitted through this to the surrounding air

PROPER MOTIONS OF THE STARS. Although the stars seem to maintain year after

year and century after century the same relative positions, there are in reality minute apparent changes of position which correspond to enormously rapid real motions. We owe to Halley the first recognition of this important fact. He noticed that the three bright stars, Sirius, Aldebaran, and Arcturus, had not the same positions on the heavens that Ptolemy assigned to them (following observations made by Hipparchus, 130 years B.C.). The change of place in the interval was considerable, the change in latitude alone being in each case greater than the moon's apparent diameter. Sir John Herschel remarks on this, that "*à priori*, it might be expected that apparent motions of some kind or other should be detected among so great a multitude of individuals scattered through space and with nothing to keep them fixed. Their mutual attractions even, however inconceivably enfeebled by distance, and counteracted by opposing attractions from opposite quarters, must in the lapse of ages produce some movement—some change of internal arrangement, resulting from the difference of the opposing actions." Such motions have been placed beyond a doubt by the comparison of the observations made in recent times with those made many years ago. In many instances the difference in the observed place of a star is so small, even after a long interval, that no reliance can be placed upon the resulting apparent proper motion. And where the interval is not sufficiently long, there can be no doubt that minute errors of observation have sufficed to give an appearance of motion where there has been in reality no change of place. Indeed, no surer test can be applied to the correctness of a new star catalogue than the examination of its adequacy to diminish the proper motions calculated from preceding catalogues. Still there can be no doubt whatever that in a large number of instances proper motions really exist. Perhaps the most satisfactory tables of proper motions yet formed are those contained in the Royal Astronomical Society's Memoirs, vols. xix. and xxviii. They have been prepared by the Rev. Robert Main, by comparing the Greenwich star catalogues with Bradley's observations recorded in Bessel's *Fundamenta Astronomiæ*. Mr. Stone has added a list of 400 stars from the same sources, which appears in the 33d volume of the Memoirs of the Royal Astronomical Society.

The present writer has exhibited reasons for believing that in the observed proper motions of the stars we have a powerful means of attacking many problems of great interest and importance in sidereal astronomy. In the 29th volume of the Notices of the Astronomical Society he has called attention to some results which seem to have an important bearing on our ideas respecting the distribution of the stars. Although in any individual instance the amount of a star's apparent proper motion cannot be supposed to indicate the relative rate at which that star is traversing space, and cannot therefore be taken as a means of estimating the star's distance, yet there can be no doubt that in taking the average proper motion of a set of stars, (say all the stars in a particular constellation, or all the stars of a given magnitude), we obtain a fair means of estimating the average distance of that set of stars. For on the average, and neglecting individual exceptions, the more distant stars will exhibit proportionately small apparent proper motions. If we wish to apply this method satisfactorily we must be careful to include a sufficiently large number of stars. When this is done the results may be accepted with some confidence. We may, for example, apply this method to determine whether the usual estimate of the distances of the fainter orders of lucid stars is correct. The writer has made this calculation, dividing the stars into two sets, the first including stars of the first three magnitudes, the second those of the next three, and taking the average for each set (the square root of the mean of the sum of squares) the strange result is obtained, that the average amount of proper motion for the three brighter orders is not greater than (and barely equals) the average for the three fainter orders of the lucid stars. There seems no way of avoiding the conclusion that by far the larger number of the fainter stars owe their faintness, not to vastness of distance, but to real relative minuteness.

It had been already noticed by Mr. Dunkin that when the effects of the sun's assumed motion are deducted from the apparent motions of the stars, on the assumption that the various orders of lucid stars lie at the distances assigned them by accepted theories, instead of an important diminution of the sum of squares, only a minute fraction of that sum is removed. (See *Proper Motion of the Sun*.) Thus the sum of the squares of motions in R. A. uncorrected for the proper motion of the sun is, for the 1167 stars considered in the inquiry by Airy and Dunkin, 78 7583, while the corrected sum is 75 5831; in like manner, the uncorrected sum for motions in N. P. D. is 63 2668, the corrected sum being 60 9084. Commenting on this, Sir John Herschel remarks, "No one need be surprised at *this*. If the sun move in space, why not also the stars? and if so, it would be manifestly absurd to expect that any movement could be assigned to the sun by any system of calculation which would account for more than a very small portion of the totality of the observed displacements. But what is indeed astonishing in the whole affair, is, that among all this chaotic heap of miscellaneous movement, among all this drift of cosmical atoms, of the laws of whose motions we know absolutely nothing, it should be

possible to place the finger on one small portion of the sum total, to all appearance indistinguishably mixed up with the rest, and to declare with full assurance that this particular portion of the whole is due to the proper motion of our own system" There is, however, a flaw in the reasoning here, though the conclusion is not the less just Sir John Herschel has omitted to notice that the mere number of the stars dealt with in solving the problem of the sun's motion can have no effect in diminishing the relative amount of the correction For the sun's proper motion affects the apparent motion of every one of the stars so dealt with, so that the correction should grow *pari passu* with the number of stars dealt with In fact, it is demonstrable—as the present writer has shown—that, let the number of stars be what it may, the value of the correction should be equal to half the uncorrected sum, if only the stellar motions be not on the average greater than the sun's, and if, further, the estimate of the distances of the several orders of stars be correct The larger the number of stars the more nearly (by a well known law of probability) should the correction approach this theoretical value The fact that the correction falls so far short of this estimate proves that either the sun's proper motion falls short of the average proper motions of the stars, or that the distances of the larger number of the stars dealt with (that is, the distances of stars of the lower orders of magnitude) have been over estimated Mr Stone has shown reasons for believing that the sun's proper motion may be held to be about three-fourths of the average proper motions of the stars And since this result would only account for a small proportion of the discrepancy, it may be accepted as certain that the stars of the lower orders of apparent magnitude are not for the most part so far off as has been supposed, in other words, that they are for the most part really smaller than the brighter orbs We have seen that this result is pointed to, also, when the proper motions are considered in a different way

The present writer has also detected the existence of a community of motion among the stars in certain parts of the heavens, a phenomenon which he denominates "star drift" If it should be established by corroborative evidence that this community of apparent motion implies real community of motion in the stars forming particular groups, it will become possible to estimate the relative distances of such stars by comparing their relative apparent motions The problem would be, in fact, merely one of perspective If, further, the absolute distance of the nearest star of the system could be determined, the absolute distances of all the known stars of the system could thus be determinable

It is possible that before long spectroscopic analysis, already successfully applied by Mr Huggins to determine the "proper motion of recess" of the bright star Sirius, will in the same able hands give information respecting the proper motions of recess or approach of many of the lucid stars This would at once enable a crucial test to be applied to the theory of "star-drift"

PROPER MOTION OF THE SUN Since the stars are observed to be slowly changing their position on the celestial sphere, it will be regarded as highly probable on *a priori* considerations, that the sun is also in motion For the sun is a member of the sidereal system, and we can conceive no reason why he alone should be exempt from the law to which all his fellows are subject Now if all the stars were at rest and the sun alone in motion, every star would seem to move towards the point in space *from* which the sun is moving The apparent motions of stars near that point and the point directly opposite to it would be minute, while the stars on a great circle of the sphere having these points as poles would seem to move more quickly than the rest (*ceteris paribus*, that is, leaving differences of distance out of consideration) But as it is utterly improbable that the sun alone of all the members of the sidereal system is in motion, and as, indeed, the character of the stellar motions suffices to prove that no motion we can assign to the sun will possibly account for all or even for a large part of them, it follows that all we can hope to recognise as a sign of the sun's motion is a general preponderance of stellar motion in one direction The problem, though difficult, has been attacked successfully by astronomers Sir Wm Herschel in 1783, by considering the apparent motions of the few stars which had been sufficiently observed in his day, arrived at the conclusion that the solar system is travelling towards the neighbourhood of the star λ in the constellation Hercules Prevost in the same year arrived at a similar conclusion, but his researches led to a point some 27° in right ascension from that determined by Sir Wm Herschel Since then the subject has been studied very carefully by many eminent astronomers, by Argelander, Lundahl, O Struve, Madler, and, finally, by Airy and Dunkin of the Greenwich Observatory The methods adopted have been various Sir Wm Herschel had simply carried great circles of the sphere through the stars he selected, and in the direction of their proper motion, and he determined the apex of the solar motion by the approach of all these circles to a common point of intersection Some astronomers, in applying calculations to the problem, have classed the distances of the stars according to their magnitudes, while others have considered the magni

tude of the stellar motions as the most satisfactory proof of relative nearness. The plan devised by Mr Airy and carried out at his suggestion by Mr Dunkin, consists in assigning to the sun such a direction and amount of motion in space as will account for the greatest possible proportion of the stellar proper motions. This plan has been carried out according to two distinct hypotheses respecting the proportion of apparent motion which may be due to errors of observation. The results obtained on these hypotheses are in tolerably close accordance considering the nature of the problem. According to one, the apex of the solar motion lies in R A 261° 14′, and N P D 57° 51′, the sun's motion being such in amount that, viewed from a distance equal to that assigned to stars of the first magnitude he could traverse 0·3346″ annually; according to the other, his annual motion, so viewed, would be 0·4103″, and directed towards a point lying in R A 263° 44′, and in N P D 65° 0′. It may be added that Mr Galloway, by considering the motions of southern stars, has arrived at a result closely according with that deduced from the motions of northern stars.

A general notion of the character of the motion of the sun in space may be obtained by considering it as taking place in a direction inclined about 60° to the plane of the ecliptic, and with a velocity such that the sun traverses in a year a space equal to about $\frac{5}{6}$ths of the diameter of the earth's orbit.

PRUSSIAN BLUE. A valuable pigment prepared by adding a solution of ferro-cyanide of potassium to excess of a per-salt of iron; it is an insoluble dark blue precipitate which has a coppery lustre when in lumps. On the large scale, it is frequently prepared by processes which yield an impure product of an inferior colour. Its composition is that of a *hydrated per-ferro-cyanide of iron* ($Fe_4(FeCy_6)_3\,18H_2O$).

PTOLEMAIC SYSTEM. The system of astronomy by which Ptolemy endeavoured to account for the celestial motions, on the hypothesis that the earth is the fixed centre of the universe. Accounting for the diurnal motion of the celestial bodies by the rotation of a vast sphere—the *primum mobile*—carrying all these objects with it, and for the annual motion of the sun and the monthly motion of the moon, by assuming these bodies to travel in eccentric circles around the earth, Ptolemy had to explain farther the looped paths of the planets, their progressions, stations, and retrogradations. To effect this, he supposed that each planet moved in a circular path termed its *epicycle*, around a fixed point, and that this point itself travelled in an *eccentric* (circle) around the sun, all motions in each order of circle being described uniformly.

As observational astronomy advanced, new contrivances had to be introduced, until at length the Ptolemaic system became very cumbrous. It need hardly be said that no amount of cyclic or epicyclic combinations could account for the motions of the planets as at present known.

PTYALIN. The active principle of saliva, a nitrogenous substance which converts insoluble starch into glucose. (See *Animal Nutrition*.)

PULLEY. One of the simple machines. It consists of a circular disc of metal or wood capable of turning about an axis passing through its centre. Usually a groove is cut in the disc to keep a cord, which passes over the pulley, from slipping off. The pulley may be considered as a lever with equal arms, so that the forces at the extremities of the cord, which passes over the pulley, must be equal in order that there may be equilibrium. A pulley, the axis of which is fixed in space, is termed a *fixed* pulley, and serves the purpose only of changing the direction of the power. If the axis be moveable, the pulley is termed a *moveable* pulley. By combining several moveable pulleys a mechanical advantage may be obtained depending on the number of pulleys and the mode of combination. The mechanical advantage of any arrangement of pulleys may be readily determined by the principle of virtual velocities. When several moveable pulleys are placed in the same block or sheave so that the same cord passes round all, and the parts of the cord are parallel, the power may be found by dividing the weight by the number of parts of the string which reach the lower block. Suppose, for example, there is one moveable pulley, then there will be two parts to the cord supporting it, so that if the weight be raised one foot, both parts will be shortened by a foot, and consequently the power must descend through two feet, or if the weight be raised by hand, two feet of cord must pass through the hand. The power is, therefore, half the weight. By a similar method it may be generally established that when there is equilibrium the power is to the weight as 1 is to twice the number of pulleys. A much greater mechanical advantage would be obtained by using a system in which the pulleys are separate and have separate strings, each string being attached by one extremity to the supporting beam, passing round one moveable pulley, and having the other extremity fixed to the pulley immediately above it. The power is applied to the cord which passes round the upper pulley. Another arrangement consists of separate pulleys suspended by separate strings, one extremity of each string being attached to the weight, but both this and the preceding combination are of little practical use. In the common arrangements all the moveable pulleys are in one block. The most powerful combination is *Smeaton's tackle*, in which

each block contains two rows of five wheels each, and one string passes round all, commencing with the centre one of the lower block, and finishing with the middle wheel of the upper.

PUMPS See *Suction Pump*, *Forcing Pump*

PUNA WINDS Cold and remarkably dry winds which blow from the Cordilleras across the table land called Puna, to the east of Arequipa in Peru

PUPIL (*Pupilla*) The central, intensely black portion of the human eye It is simply a circular aperture in the iris, through which the black interior of the eye is visible (See *Eye*)

PUTREFACTION (*Putridus*, rotten, and *facio*, to make) The decomposition of nitrogenous animal and vegetable substances under the influence of atmospheric oxygen and a suitable temperature Putrefaction is supposed to be induced by the presence of minute germs floating in the atmosphere Professor Huxley, President of the British Association, in his opening address at Liverpool in September 1870, entered into full details respecting this obscure action of atmospheric germs Dr Angus Smith and Professor Tyndall have also published much on this subject

PYRHELIOMETER (πῦρ, fire, ἥλιος, the sun, μετρέω, to measure) An instrument devised by M Pouillet for measuring the intensity of the heat of the sun It consists of a shallow circular vessel of silver containing water or mercury in which a thermometer is plunged The upper surface of the vessel is covered with lamp black, so as to render it a good absorber of heat, and the thermometer enters its under surface, and thus extends below it An arrangement is made for causing the rays of the sun to fall perpendicularly upon the surface of the vessel An observation with this instrument is made in the following manner —When the water in which the thermometer is plunged possesses the exact temperature of the surrounding atmosphere, the instrument is placed in the shade and allowed to radiate its heat against a clear sky for five minutes The loss of heat is noted, and we may call this r The blackened surface is now exposed to the full rays of the sun for five minutes, and the rise of temperature of the water, as shown by the immersed thermometer, is noted, we will call this R The instrument is finally again placed in the shade, and allowed to radiate its heat into a clear sky for five minutes, this loss may be called r' It is not sufficient to simply expose the pyrheliometer to the sun and then note the rise of temperature, because the instrument is radiating heat into space during its exposure to the direct rays of the sun, and a portion of the heat received from the sun is thus wasted Hence the total heating effect is obtained by adding the amount thus lost to the amount directly acquired from the sun As r represents the heat lost by radiation by the instrument before exposure to the sun, and r' the amount lost after exposure, the amount lost during exposure may be considered the mean of the two, or $\frac{r+r'}{2}$, and the entire heating effect of the sun H will therefore be represented by

$$H = R + \frac{r+r'}{2}$$

The actual amount of heat absorbed by the instrument is calculated by ordinary calorimetrical means, the area of the exposed blackened surface is known, and the amount of water which has been raised through a certain number of thermometric degrees is known, and thus the absolute heating effect of the sun, acting upon a given area under the conditions of the experiment can be readily found Pouillet used about 1500 grains weight of water for his experiments His results have been described elsewhere (See *Heat, Sources of, Solar Heat*, Experiments on the same subject were made by De Saussure, Sir John Herschel, and Professor Forbes The first instrument for the purpose was devised by De Saussure, and in 1825 Herschel invented his *Actinometer*, which see

PYRITES A name used in mineralogy to denote several metallic sulphides Thus there are *copper pyrites* ($Cu_2S\ Fe_2S_3$), *iron pyrites* (FeS_2), *magnetic pyrites* (Fe_7S_8), *tin pyrites* ($Cu_2S\ (SnS_2Fe_2S_3)$), *arsenical pyrites*, or mispickel ($FeAsS_2\ FeS_2$), *variegated pyrites* ($FeS\ 2Cu_2S$)

PYRITES, IRON See *Iron, Sulphides*

PYRO-ELECTRICITY A name given to electricity produced by heating or cooling certain crystals The subject, though it has attracted much attention, still remains very obscure. The phenomenon is this —Certain crystals, among which are tourmaline, boracite, topaz, axinite, prehnite, &c, on being heated exhibit electric excitement Thus a crystal of tourmaline becomes positively electrified at one extremity and negatively at the other In boracite some of the faces are electrified positively, and some negatively If a tourmaline thus electrified be kept hot it soon loses this electric polarity and resumes its natural condition, and if it then be allowed to cool, that end which formerly was positive becomes negative, and *vice versa* The conditions under which electric excitement of this kind takes place have been investigated by Æpinus, Canton, and Hauy

PYROGALLIC ACID A product of the action of heat on gallic acid It crystallises in long white needles, very soluble in water, and having the composition $C_6H_6O_3$ It acts as a powerful reducing agent, and is much used in photography

PYROLIGNITE OF IRON See *Acetates, Acetate of Iron*

PYROLIGNEOUS ACID See *Acetic Acid*

PYROLUSITE See *Manganese Oxide*

PYROMETER (πῦρ, fire, μετρέω, to measure) The mercurial thermometer is necessarily limited in its indications to the temperature at which mercury boils (350° C, or 662° F), because at that temperature the vapour of mercury would be formed, and its pressure would burst the thermometer Pyrometers are instruments which are used to measure high temperatures, and although several forms of this instrument have been devised, it cannot be said that any one possesses accuracy The most accurate determinations of high temperatures which have yet been made are due to Regnault, Deville and Troost, and Pouillet, and were either made by means of an air thermometer, or by some form of gas thermometer (or pyrometer), in which vapour of mercury or vapour of iodine was employed (See *Air Thermometer*) By means of an air pyrometer, Pouillet determined the following temperatures, which correspond to the various degrees of incandescence which a metal passes through, when placed in a furnace —

Incipient red heat,	525° C, or	977° F
Dull red, .	700	" 1292
Cherry red, .	900	" 1652
Dark orange, ...	1100	" 2012
White, .	1300	" 2552
Dazzling white, ...	1500	" 2732

Of the old forms of pyrometer the principal are those devised by Wedgwood, Daniell, and Brongniart, but the inaccuracy of these instruments has quite prevented their employment, except for the indication of roughly approximate temperatures in the arts, as in glass or porcelain furnaces Wedgwood's pyrometer depends on the fact that dry clay when exposed to high temperatures contracts uniformly, and, by measuring this contraction, it was imagined that the heat which had produced it might also be measured, the instrument was found, however, to be altogether untrustworthy This pyrometer was invented in 1782 About twenty years later, Guyton de Morveau devised a pyrometer in which the temperature was measured by the expansion of platinum, indicated by a multiplying index A similar instrument was used by Brongniart for determining the temperature of the furnaces in the porcelain manufactory at Sèvres He employed a rod of iron or platinum which was fixed at one end while the other pressed against a lever, serving as an index The rod was enclosed in a tube of porcelain Professor Daniell also used a bar of platinum, and enclosed it in a tube of plumbago Several forms of electric pyrometer (based on the formation of a thermo electric current, when two dissimilar metals are heated at their juncture), have been proposed by Pouillet and Becquerel The latter has also proposed to determine high temperatures by measuring the intensity of the light emitted by the heated body, and by such means he estimates the fusing point of platinum at 1600° C (2912° F), and the heat of the voltaic arc at 2070° C (3758° F) (See also *Temperature, Air Thermometer*)

PYROXYLIN. See *Gun-Cotton*

Q

QUADRANT (*Quadrans*, a fourth part) An instrument formerly much used in astronomy, especially for determining altitudes The difficulty of constructing a true quadrant, and the fact that there are no ready means for correcting the indications of the instrument led to the introduction of circular instruments, now constantly employed in astronomy in those cases where formerly the quadrant was used

QUADRATURE (*Quadratus*, four-square) In astronomy, the moon or a planet is said to be in quadrature when its place differs 90° in longitude from the sun

QUALITATIVE ANALYSIS See *Analysis, Chemical*

QUALITY OF HEAT The heat emitted from different sources varies, as is proved by Melloni's experiments on absorption, for he found that the same substance absorbed different quantities of heat according as the source of heat was changed The term *quality* of heat signifies any variation in radiant heat which causes it to be differently absorbed or transmitted by substances Thus, according to Melloni, glass $\frac{1}{10}$th of an inch thick transmits 39 per cent of the rays emitted by a Locatelli lamp, 24 of those emitted by an incandescent spiral of platinum, 6

of those emitted by copper at 400° C., and none of those emitted by copper at 100° C. It is very clear, therefore, that the quality of the heat emitted by these different sources varies considerably. If any other source of heat could be found of such a nature that glass $\frac{1}{10}$th of an inch thick transmitted 6 per cent. of the total emission, then the *quality* of that heat would be precisely the same as that emitted by copper at 400° C. Quality depends upon the wave length of the ether conveying the motion of radiant heat, and upon its period of vibration, and mode of vibration—that is, whether or no it be polarised, and in what plane. Heat of one absolute quality is perhaps most readily and perfectly obtained by enclosing a spiral of platinum in a vacuous chamber with rock salt windows, and raising the spiral to incandescence by means of an electric current of known, constant, and invariable intensity.

QUANTITATIVE ANALYSIS. See *Analysis, Chemical*.

QUANTITY, ELECTRIC. Electric quantity is measured by the force which the charge upon a body gives rise to. "When the force between two bodies at a constant distance, and separated by air, is seen to increase, it is said to be due to an increase in the quantity of electricity, and the quantity at any spot is defined as proportional to the force with which it acts through air on some other constant quantity at a distance." Unit of quantity is that quantity which, when placed at unit of distance from an equal quantity, attracts or repels it with unit of force.

QUARTZ. The name given to crystallised silica, SiO_2. It occurs either in the massive form when it is milky white, or tinged with iron and in distinct crystals; the crystals are six-sided prisms with pyramidal summits; cleavage is very imperfect, and twins are of frequent occurrence. Hardness 7; specific gravity 2.5 to 2.8; lustre vitreous; it is of all colours, from perfectly colourless to black, passing through shades of yellow, red, brown, green, blue, and black, owing to the presence of metallic oxides. When colourless and transparent, it is usually called *rock crystal*; when purple *amethyst*; when rose red, or pink, *rose quartz*; when light yellow, *false topaz*; when of a brownish smoky tint, *smoky quartz* or cairngorm; when leek green and opaque, *prase*; when spangled throughout with yellow scales, *aventurin quartz*. Other varieties are known as chalcedony, jasper, siderite, flint, horn stone, opal, &c. For the chemical properties of quartz, see *Silica*.

QUICK LIME. See *Calcium, Oxide of*.

QUICKSILVER. See *Mercury*.

QUININE. An organic alkaloid, forming the most important active principle of the cinchona bark. It usually appears as a white, porous, friable mass, permanent in the air, free from odour, and exceedingly bitter. Its composition is $C_{20}H_{24}N_2O_2$. It is almost insoluble in water, but more soluble in alcohol and ether. It has a strong alkaline reaction to test paper, and neutralises acids forming salts, which usually crystallise well. Salts of quinine are of two classes, neutral salts and acid salts. They are generally soluble in water, and have a very bitter taste, and frequently exhibit a silky lustre. The only salts of importance are the sulphates; commercial *sulphate of quinine*, improperly called basic sulphate of quinine, is really the neutral salt, its formula being $2C_{20}H_{24}N_2O_2 \cdot H_2SO_4$. It crystallises in long flexible needles, very light and efflorescing on exposure to the air. The anhydrous salt requires about 800 parts of water to dissolve it, but only about 100 of alcohol; the addition of a little dilute sulphuric acid to the water converts this salt into the acid sulphate, which only requires 10 parts of water to dissolve it. The solution of sulphate of quinine in dilute sulphuric acid is strongly fluorescent, exhibiting a beautiful azure blue colour. Sulphate of quinine is one of the most valuable medicines we possess, and is manufactured in enormous quantities as a febrifuge. (See *Cinchona Bark, Alkaloids from*.)

QUINIDINE. A base which has the same composition as quinine, and occurs associated with it in some cinchona barks. It crystallises in large transparent prisms, almost insoluble in water, but tolerably so in alcohol. It neutralises acids, and forms salts with them, which much resemble the corresponding quinine salts, but crystallise more easily.

R

RACEMIC ACID. See *Tartaric Acid*.

RACK AND PINION. (Rack, from Anglo-Saxon, *ræccan*, to reach, extend; German, *recken*, to stretch; so rack is a bar which is extended, or whose teeth are pushed forward. Pinion, from Norman French, *pignon*, a pen; Lat., *pinna*, *penna*, feather-wing.) The term pinion is generally applied to a comparatively small toothed wheel working in the teeth of a much larger one, and is specially applied to a wheel constructed on the axle of a larger wheel, and moving with the larger wheel. The contrivance known as rack and pinion is one for producing

a limited rectilinear motion from a circular one A toothed wheel or pinion rotating about its axis is caused to work in a straight toothed bar Of course, the extent of the motion is limited by the number of teeth on the bar (See *Jack*)

RADIANT HEAT (*Radius*, a rod, the spoke of a wheel , related to ῥαβδος *Radio*, to emit beams, to shine, is not unfrequently used by the ancients , thus Lucretius, "radiantia lumina solis") The motion which constitutes heat may either be associated with ponderable and directly recognisable matter, or it may exist in the form of *radiant heat* When associated with matter, we have noticed that it produces various changes, notably of condition, as in the solid, liquid, and gaseous conditions of matter Radiant heat is transmitted by an unseen medium , the heat which comes to us from the sun is radiant heat, as is also the heat which we perceive when we stand in the presence of a heated mass, such as the fire, or a piece of red-hot metal A hot body parts with its heat until it assumes the temperature of surrounding substances , if, for instance, we suspend a red hot poker by a piece of string in mid air, we find that it gradually loses its heat, and ultimately becomes what we term cold That this heat is not communicated to the air is proved by the fact that a substance suspended by a non conductor of heat in the most perfect vacuum we can obtain, loses its heat Radiant heat is thus capable of traversing a vacuum, and this was proved early in the century by Rumford and Davy The former suspended a thermometer in an exhausted receiver by a silk thread , and on placing a warm substance outside the receiver, and opposite the bulb of the thermometer, he found that a rise of temperature was indicated Davy placed two reflectors in an exhausted receiver, and proved that a hot substance placed in the focus of one reflector caused an increase of temperature at the focus of the other Hence the transmission of radiant heat is entirely independent of the air, or of any medium which we can recognise by direct means

Beyond the limit of our atmosphere, and filling all space, we believe there is an infinitely thin and subtle medium which is called the ether, the luminiferous ether, and the interstellar medium, indiscriminately (See *Ether, Luminiferous*) All radiant actions—light, heat, radiant chemical action, and so on—are held to be transmitted by undulations of this medium The undulations which constitute radiant heat would appear to be of the same character, and to travel with the same velocity as those which constitute light, but the individual vibrations producing heat are slower than those of light If we take a mass of metal and gradually heat it it first becomes warm , then as it receives more of the motion of heat, its molecules vibrate more quickly, and it becomes hot , then it assumes a dull red tint, that is, it begins to emit red light , and as the heating is continued, the mass becomes orange, yellow, blue, until it ultimately glows with an intense white heat—that is, it emits white light By gradual addition the heat has increased, and has ended in light and heat together So, again, in cooling, the reverse effect takes place, until the mass ceases to be luminous, and then after a while ceases to be perceptibly hot Heat obeys the same laws as light, in regard to its variation in intensity, as the distance increases, and also as to its reflection, refraction, and polarisation, and there are additional reasons for the belief that light and heat are modifications of the same action, differing not in kind, and only slightly in degree

Radiant heat is the motion of heat transmitted to the ether, which motion is propagated in the form of waves through the ether Thus when a hot substance is cooling it is communicating its motion on all sides to the surrounding ether, and this occurs in a vacuum equally as in air, because the luminiferous ether is so infinitely subtle that it passes through the densest substances and pervades them , thus an exhausted receiver is as full of the ether as before exhaustion, and for this reason a warm body cools when placed in it Now, as a hot body which is cooling communicates its motion of heat to the ether in straight lines in every direction, like the *radii* of a circle, or (to go back to the more direct derivation) the spokes of a wheel, the action is known as *radiation*, and the motion thus transmitted as *radiant heat* (See also *Absorption of Heat*, *Calorescence*, *Dynamic Heating of Gases*, *Heat Spectrum*, *Obscure Heat*, *Polarisation of Heat*, *Radiation of Heat*, *Reflection of Heat*, *Refraction of Heat*

RADIANT POINT See *Diverging Rays*

RADIATION OF HEAT Radiant heat has been defined above as heat propagated in straight lines through the ether or interstellar medium in the form of undulations, and after the manner of light Radiation is the communication of the motion of heat from the particles of a heated substance to the ether All substances radiate heat, and the rate of radiation depends upon the difference of temperature between the substance radiating and proximate bodies (See *Theory of Exchanges*) The radiating power of different substances varies considerably, and is to a great extent dependent upon the nature of the surfaces If we take a cube of tin, one surface of which is brightly polished while another is coated with lamp-black, and fill it with boiling water, we find that the effect of the different sides upon a thermometer placed at the same distance from each side is very different. When the thermometer is placed opposite the

blackened side the temperature rises considerably, because lamp black is a good radiator of heat, and readily transmits the motion of heat to the surrounding ether, on the other hand, the thermometer is scarcely affected when the bright surface of the cube is presented to it, because the metal is a bad radiator, and cannot transmit the heat of the boiling water within the cube to the surrounding ether. If, however, the polished metal surface is covered with a good radiator, as by covering it with a layer of varnish, copious radiation is at once manifest. It is clear, therefore, that if there are two vessels filled with boiling water, and if one is composed of a good radiator of heat and the other of a bad radiator, the former will cool soonest. Hence boiling water placed in a blackened vessel will cool sooner than if it were placed in a polished vessel, and, for the same reason, water cools sooner in a kettle covered with soot than in one which is bright, and in an earthenware teapot than in one of polished silver. Good radiators of heat are also good absorbers—in other words, substances which readily transmit the motion of heat to the ether also readily absorb it from the ether. (See *Absorption of Heat*.) If we place a blackened surface and a brightly polished surface side by side in front of a fire, the former will quickly acquire heat by absorption, while the latter will reflect nearly all the radiant heat which falls upon its surface. Or we may vary the experiment by coating the bulb of a thermometer with tinfoil and holding it at a certain distance from a source of heat, the mercury is scarcely affected, because the heat is almost entirely reflected from the bright metal. If we now strip off the tinfoil, the mercury rises at once, because the glass of the thermometer bulb is a better absorber, and hence worse reflector, of heat than the tinfoil, but if, lastly, we cover the bulb with lamb black, the mercury will rise more rapidly than before, because the lamp-black is a better absorber of heat than the glass, and reflects none of the rays falling upon it. Of the total amount of radiant heat which falls upon a surface a portion is absorbed and the rest reflected, hence the reflecting power is the complement of the absorbing power. In a few instances the absorption is complete. The radiating and absorbing powers go hand in hand, they are reciprocal actions. In the following table (which is given by M. Pouillet in his *Eléments de Physique Expérimentale*) the radiating and absorbing powers of various substances, with their reflecting powers, are shown side by side —

Names of Substances	Radiating and absorbing power	Reflecting power	Names of Substances	Radiating and absorbing power	Reflecting power
Lamp black,	100	0	Brass, cast, roughly polished,	11	89
Carbonate of Lead,	100	0	Brass, hammered, roughly polished,	9	91
Writing paper,	98	2	Brass hammered, highly polished,	7	93
Glass,	90	10	Brass, cast, highly polished,	7	93
China ink,	85	15	Copper, deposited on iron,	7	93
Gumlac,	72	28	Copper, hammered or cast,	7	93
Silver foil on glass,	27	73	Gold plating,	5	95
Cast iron, polished,	25	75	Gold, deposited on polished steel,	3	97
Mercury,	23	77	Silver hammered and highly polished,	3	97
Wrought iron, polished,	23	77	Silver, cast and highly polished,	3	97
Zinc, polished,	19	81			
Steel,	17	83			
Platinum, imperfectly polished,	24	76			
Platinum, deposited on copper,	17	83			
Platinum foil,	17	83			
Tin,	14	86			
Metallic mirrors, tarnished,	17	83			
Metallic mirrors, freshly polished,	14	86			

Some of these results were obtained by Melloni, but those which relate to polished metallic surfaces are from the experiments of MM. de la Prevostaye and Desains. The numbers given in the above table do not remain quite the same for all temperatures and for all sources of heat, thus, in regard to solar heat, the lamp-black and carbonate of lead are not found to have precisely the same absorbing power, for the former absorbs rather more of this heat than the latter.

Radiation takes place through a vacuum, as was proved by Rumford. Moreover, the heat of the sun traverses space, which we believe to be absolutely vacuous, before reaching us. That radiation takes place in straight lines, and equally in every direction, is implied by the term itself. (See also *Radiant Heat*, *Diathermancy*.)

RADIUS VECTOR (*Radius*, and *vector*, a carrier) In astronomy, a straight line supposed to be drawn from a central orb to a body travelling in an orbit around it

RADICAL (*Radix*, *radicis*, a root) The basis of a compound Gerhardt's definition is "the proportion in which certain elements or groups of elements may be substituted for others, or may be transferred from one body to another in the act of double decomposition" (See *Radical, Compound*)

RADICAL, COMPOUND In organic chemistry, a compound radical is a group of elements which, in the various changes and decompositions which a substance undergoes, remains unaffected, and acts as if it were an element, thus cyanogen, cacodyl, ethyl, the group NO_2, &c, are compound radicals

RAG WHEEL A mechanical contrivance for converting rotatory motion into rectilineal or the reverse, in which the teeth of a wheel are caused to work in the links of a chain

RAIN Water falling in drops from the upper regions of the air The actual process of the production of rain has not yet been completely explained, nor perhaps will it be until we know more of the constitution of clouds, and especially of the structure of their constituent globules De Saussure, Kämtz, and Kratzenstein think that these globules are hollow, whereas Sir John Herschel and Dr Tyndall suppose them to be simply minute water drops "It is certain," says the latter, "that they (the globules) possess, on or after precipitation, the power of building themselves into crystalline forms, they thus bring forces into play which we have hitherto been accustomed to regard as molecular, and which could not be ascribed to the aggregates necessary to form vesicles"

The general causes leading to the precipitation of rain are probably the following —

(1) The cooling of clouds through the effects of radiation

(2) The commingling of nearly saturated masses of air at different temperatures (See *Saturation*)

(3) The ascent of masses of moisture laden air towards colder regions

(4) The impact of such masses against some cold surface

(5) The transfer from equatorial towards polar regions of large masses of moisture laden air by means of the upper south westerly or *counter trade winds*

The increase of atmospheric density or pressure is sometimes added, but as such a change is always accompanied by an increase of temperature it does not cause condensation Dr Tyndall, speaking of such a process, says, "The heat developed is more than sufficient to preserve the moisture in the state of vapour"

Electricity is regarded by many meteorologists as largely operative in causing the precipitation of rain, but though it is true that no rain storm ever takes place without electrical action being developed, we ought rather, it would seem, to regard this action as the effect than as the cause of the precipitation

The circumstances affecting the action of these several causes in different places are chiefly the following —The latitude of the station, the elevation above the sea level, the proximity of the sea, the laws affecting the seasonal variations at the place, the prevailing winds, and the configuration of the surrounding surface Some of these circumstances have been considered under the head *Climate*

In general, low latitudes are regions of heavy annual rainfall The rapid evaporation which takes place over moist regions under the tropical sun causes ascending air currents, and the upper regions of the air being rarer and colder than the lower, and radiation of heat taking place rapidly from the upper surface of clouds—brought here, as Tyndall expresses it, into the presence of pure space—(dry air having no appreciable effect in checking radiation), there results a copious precipitation Over the equatorial regions, therefore, and in a less degree in tropical and sub tropical regions (with some notable exceptions, however) clouds are formed by the action of the sun, and their formation is followed presently by the precipitation of heavy rain showers Humboldt estimates the average depth of rain falling in latitudes 0°, 19°, 45°, and 60°, at 98, 80, 29, and 17 inches, respectively

Winds blowing towards the equator are commonly dry, and winds blowing from the equator are commonly moist We venture, in place of the explanation commonly given of this circumstance, to refer the peculiarity to the simple fact that winds of the former order are blowing from regions where the air is *less*, to regions where it is *more* heavily laden with moisture, and *vice versa*

Forests are great generators of rain (see *Forests, Influence of, on Climate*), and as rain in turn encourages vegetation, a forest-covered region tends to remain unchanged in character, or to be covered year after year with a ranker luxuriance of vegetable growth And, in like manner, arid regions tend to remain arid, even where an attempt is made to change their character,

because the intense heat of the soil and the dryness of the superincumbent air prevent even moisture-laden winds from bringing rain to nourish vegetation

The influence of the seasons on rainfall varies with the latitude Under the tropics the laws affecting the fall of rain are much more regular than elsewhere On the ocean we have clear skies where the trade-winds are blowing steadily, and heavy rain falls by day over the intermediate zone of calms, but on the land we have a regular alternation of dry and wet seasons In what we must call the winter of the tropics (see *Climate*), the sky is serene, in spring it becomes moist, and the rainy season sets in when the sun is near the zenith When the interval between the sun's successive passages of the zenith is long (as at the equator) there are two wet seasons, both occurring in the summer months When monsoons prevail, however, the alternation of dry and wet seasons depends on the winds When the southwest monsoon is blowing over India, for instance, there is no rain on the east coast, but abundant rain on the west coast During the north east monsoon these conditions are reversed

Beyond the tropics, with inconstant winds we get variable rainfall In England, in particular, the rainfall is remarkably variable whatever season or month we consider In the British Isles, too, the Gulf Stream, while adding on the whole to the supply of rain, causes peculiarities of a very marked character in the distribution of the supply Winds from the east often drive back the moisture-laden south-westers, especially in spring At such times the air becomes singularly dry

The rainless regions of the earth are—the coast of Peru in South America, the valley of the rivers Columbia and Colorado in North America, the Sahara in Africa, and the desert of Gobi in Asia

The heaviest annual rainfall on the globe occurs on the Khasia Hills, where no less than 600 in[illegible] the course of a year, 500 falling during the seven months' continuance of the [illegible] monsoons The following estimates of annual rainfall in tropical places as they are from Buchan's Handybook of Meteorology —Singapore, 97 inches, Canton, 78 St Benoit, 163, Sierra Leone, 87, Caraccas, 155, Pernambuco, 106, Rio Janeiro, 59, Georgetown, 100, Barbadoes, 72, St Domingo, 107, Bahamas, 52, Vera Cruz, 183, Cuba, 60, Doldrums of the Atlantic, 225, and Maranhao, 280

In Europe, the westerly countries have, for the most part, the greatest rainfall At Coimbra, the annual rainfall amounts to 123 inches, while at Petersburg it is but 18·2 In the British Isles the rainfall varies remarkably At Skye, in the lake district, the annual rainfall is about 224½ inches, at Seathwaite in Cumberland, 183½, but in the eastern parts the rainfall varies from 20 to 28 inches In France the average is 30 inches, in the plains of Germany and Russia, 20 inches

We owe to Mr Symons the attention which has of late years been paid to the subject of rainfall in Great Britain

See further Kaemtz's Meteorology, translated by Mr C Walker, Daniell's Meteorological Essays, the writings of Dové, Glaisher, &c, and Keith Johnston's Physical Atlas

RAINBOW A luminous arc sometimes seen in the sky opposite the sun during rain It is formed by the rays of light being reflected from the inner surface of the spherical drops of rain, and refracted and dispersed as they enter and quit the drops The result is a multitude of coloured spectra, as many, in fact, as there are drops of rain But out of the whole number only those which are reflected in a certain direction can come to the observer The light forming the rainbow makes the shell of a cone, whose apex is at the observer's eye, while the radius of the circle forming the base is about 41° It follows, therefore, that no two people can see actually the same bow, as each person receives the light from different drops The colours are the same as in the solar spectrum, the innermost being violet, and the outermost red Under very favourable circumstances a much fainter bow, called the secondary rainbow, is seen outside the principal or primary rainbow It is due to two reflections and two refractions Occasionally a third has been seen The light of both rainbows is polarised in planes passing through the eye and the radii of the arc. (See *Reflection of Light, Total, Refraction*)

RAINFALL The amount of rain falling in a given period (See *Rain*)

RAIN GAUGE. An instrument for measuring the fall of rain The simplest form is a metallic cylinder, with a glass tube (divided into inches and parts) rising from the bottom A float, with an attached scale rising above the level of the rain gauge, is sometimes used, as the glass tube is apt to break during frosty weather In some rain gauges the aperture is much larger than the diameter of the vessel in which the rain is collected Mr G J Symons recommends this sort for general use A form devised by the late G V Jagga Rao, of Vizagapatam, is worthy of notice on account of its cheapness and simplicity

Rain-gauges, so devised as to indicate the varying rainfall with different winds, to have their

aperture always at right angles to the wind, and to answer other purposes, have been devised by Mr Symons and others

A rain gauge must be placed close to the ground, as elevation causes a marked diminution in the amount of fall. The cause of this peculiarity has not yet been satisfactorily explained. Dr Franklin suggested that the condensation of the aqueous vapour of the atmosphere on the rain-drops as they fall may be the cause; but Sir John Herschel has shown that only a seventeenth part of the increase can be ascribed to this cause.

RAMSDEN'S EYE-PIECE. See *Positive Eye-piece.*

RANGE OF A PROJECTILE. See *Projectiles.*

RAREFACTION (*Rarefacio*, to rarify). The action of a property possessed by gases and aeriform fluids by which the intervals between the particles of matter composing them may be increased or diminished, so that the same weight of the gas occupies a greater space. Rarefaction is produced by diminishing the pressure or by increasing the temperature. It is directly proportional to the diminution of pressure, and no limits to it have as yet been discovered. However small a quantity of gas may remain in a given space it is shown by Geissler's vacuum tubes that the gas occupies the whole of the space.

RAS ALGETHI (Arabic). The star *a* of the constellation Hercules.

RAS ALHAGUE (Arabic). The star *a* of the constellation Ophiuchus.

RATCHET WHEEL (French, *rochet*, Italian, *rocchetto*, a spindle; *rocca*, a distaff). See *Jack.*

RAYS, CONVERGING. See *Converging Rays.*

RAYS, DIVERGING. See *Diverging Rays.*

REACTION. See *Action.*

REACTION, CHEMICAL (*Re*, again, and *ago*, *actum*, to put in motion). The action of chemical agents on each other. (See *Reagent.*)

REAGENT. A chemical test which serves to distinguish the presence of a substance or group of substances by the mutual action which they exert on one another.

REALGAR. See *Arsenic, Sulphides of.*

REAL IMAGE. See *Images, Virtual, Real.*

RECOMPOSITION OF WHITE LIGHT. If light, which has been dispersed into its primary colours by means of a prism, be passed through another similar prism, held in the reverse direction, the colours are refracted back again, and caused to travel in its original direction forming white light again. If the spectrum be received upon a series of small mirrors (say seven), and these be turned so as to reflect the incident colours on to one spot of a white screen, they will reform white light. If a circular disc be divided into seven portions by radii, and these be painted with the seven colours, on causing the disc to rotate rapidly, the persistence of vision will cause the seven colours to be present on the retina at the same time, and the result will be a uniform gray tint, if the spaces for each colour have been carefully apportioned. The reason why white is not produced in this experiment is, that artificial pigments never reflect pure colours but mixtures; the purer the colours the more nearly the gray approaches white. (See *Colours of Bodies.*)

RED LEAD. See *Lead, Oxides.*

RED LEAD ORE. See *Chromates, Chromate of Lead.*

RED OXIDE OF MANGANESE. See *Manganese, Oxides.*

RED PRECIPITATE. See *Mercury, Oxides.*

RED STARS. See *Stars, Colours of.*

REDUCTION (*Re*, back, and *duco*, to lead). The separation of oxygen, chlorine, or allied elements from a metallic compound so as to leave the pure metal, is usually termed reduction. But the term is frequently extended to an incomplete action of this sort, or even to the addition of hydrogen.

REED PIPES. The reed applied to an organ pipe or other sounding pipe, acts as a spring valve whose motion permits successive puffs of air to pass through. The simplest form of reed pipe consists of a short pipe closed at one end. A strip of the pipe running along it and near to the closed end is removed. A spring, slightly concave, is fastened to the tube at one end, the other being free. When the spring is bent flat it either covers the hole entirely (clapper reeds), or passes into the opening (free reeds). If the closed end of the reed is placed in the mouth or other vessel of air, and the air is forced into the tube, the valve will be slammed and the current stopped. If the latter be not too strong, so that the reed spring is shut by the friction and momentum of the air passing by it, and not by the steady pressure of the air, the valve will open when the current is stopped, and allow a fresh current to be established. In this way a succession of air puffs will pass by the reed which, if sufficiently rapid in their succession, will constitute a musical note. The pitch of the

note, depending upon the rate at which the reed vibrates, can be changed by shortening the free end of the reed; this is done by sliding a wire along it from the root towards the free extremity. When the reed is applied to an organ pipe, the note produced depends upon the length of the pipe (see *Organ Pipe*), rather than upon the length of the reed. (See *Vibration of Elastic Rod*.) In fact, when the note in the pipe is established, the reed obeys the impulses it receives from the air in the tube. Its use is accordingly rather to economise the air and to give certainty and precision to the striking of the note.

REFLECTING MICROSCOPE. A form of microscope devised by Amici, in which a *reflecting mirror* is used instead of the *object glass*. The object being placed in one of the conjugate foci near to the mirror, an image is formed in the other focus about 10 inches off, and is examined by an eye-piece; this form is now obsolete. (See *Microscope*.)

REFLECTING TELESCOPE. Reflecting telescopes are almost entirely used for astronomical purposes. In them light from the object falls upon a concave *speculum* and is thence reflected either to a mirror, or to an eye-piece, according to the particular construction of the telescope. (See *Cassegrainian, Herschelian, Gregorian, and Newtonian Telescopes*.)

REFLECTION, ANGLE OF. See *Incidence, Angle of*.

REFLECTION, LIGHT LOST BY. See *Light Lost by Reflection*.

REFLECTION OF COLD. See *Theory of Exchanges*.

REFLECTION OF HEAT. (*Reflecto*, to turn back.) When radiant heat impinges upon a polished surface it is reflected, or turned back. The ordinary reflector of our kitchens is used for this purpose, and the brighter its surface the more does it concentrate heat upon the things within it. The reflection of heat was well known to the ancients. According to Pliny, the sacred fire of Vesta was rekindled by reflecting the rays of the sun from a metallic mirror. Porta mentions that heat, sound, and cold may be reflected by mirrors in precisely the instances they mention. Now, as thermometers were not yet invented, he probably detected this by placing his hand in front of the mirror, but this test was not sufficiently delicate in the case of the reflection of cold, consequently he placed his eye in the focus [illegible] the most delicate organism of the body, just as some two-and-half centuries later Dr. Tyndall daringly placed his eye in a focus of dark heat rays, in order to see whether any light accompanied the heat. The following is the account of Porta's experiment, from the seventeenth book of the celebrated *Natural Magic*: "Calorem, frigus, et vocem, speculo concavo reflectere." "Si quis candelam in loco, ubi spectabilis res locari debet apposuerit, accedet candela per aerem usque ad oculos, et illos calore et lumine offendet, hoc autem mirabilius erit, ut calor, ita frigus reflectitur, si eo loco nix objiciatur, si oculum tetigerit, quia sensibilis etiam frigus percipit." Bonaventure Cavalieri, writing in 1632, mentions that he inflamed dry substances by reflecting the heat of burning charcoal from a spherical mirror, and when a parabolic mirror was substituted, he could produce the effect at a distance of five feet, with a small fire of wood as the source of heat. About fifty years later Tschirnhausen constructed a mirror of polished copper, nearly 6 feet in diameter, which readily melted very refractory substances. The largest burning mirror ever constructed was devised by Buffon, and consisted of a hundred small mirrors of looking glass arranged on a frame, so as to be capable of easy adjustment in any position; by means of this he could inflame wood at a distance of 200 feet from the surface of the mirror.

Dark heat is reflected in the same manner as light, and according to the same law; that is to say, the angle of incidence of a ray of heat is equal to the angle of reflection; it impinges upon a reflecting surface at a certain angle, and it leaves the surface at the same angle. If we place an air-thermometer or thermo-electric pile in the focus of a spherical, or better, a parabolic mirror, and place a vessel containing hot water in front of, but at some distance from, the mirror, we notice an immediate indication of heat. The rays of heat proceeding from the hot water have impinged upon the surface of the mirror, and been thence reflected upon the air thermometer. If two parabolic mirrors are placed face to face, with their axes perfectly coincident, and a source of heat be placed in the focus of one of them, the reflected heat is very evident at the focus of the other, although a space of several feet may intervene between the two. Phosphorus may thus be ignited by the heat reflected from a ball of metal below redness, and the effect upon a blackened air thermometer is very marked. The reflecting powers of substances vary greatly; a comparison is made between the radiative and reflective power of various substances in the table given under the heading *Radiation of Heat*. It will be noticed that the metals which reflect heat most completely also reflect light very readily; moreover, that good reflectors of heat are bad radiators, and *vice versa*. In all matters connected with reflection dark heat and light resemble each other perfectly. See also *Theory of Exchanges*.

REFLECTION OF LIGHT. When a ray of light falls upon a polished surface it is reflected or turned away from its original course. The angle which the incident ray forms with the plane reflecting surface is equal to the angle which the reflected ray forms with the same

surface Parallel rays of light incident on plane mirrors remain parallel, when incident on concave mirrors they are converged to a focus, and when incident on convex mirrors they become divergent A concave reflector is frequently used instead of an object glass in astronomical telescopes (See *Reflecting Telescope*)

REFLECTION OF LIGHT FROM METALS See *Metals, Colours of*

REFLECTION OF LIGHT, TOTAL When a ray of light passes obliquely from a rarer into a denser medium, the sine of the incident ray is always greater than the sine of the refracted ray, and a considerable portion enters and is refracted, however great may be its obliquity, but the converse of this does not hold good If a ray passes from a dense medium into a rare one, the sine of refraction will exceed that of incidence, and when the ray is incident at a greater angle than that at which the sine of the refracted ray would be equal to the radius, the refraction of the ray becomes impossible, and, instead of entering the rarer medium, it is reflected back again from the internal surface of the denser, if the obliquity be sufficient no light is lost, and the brilliancy of the light thus reflected far exceeds that from the best metallic mirrors (Brooke's Natural Philosophy, p 1060, and Brewster's Optics, p 31) The angle at which internal reflection occurs is termed the *limiting angle*, which see, also *Right Angled Prism*

REFLECTION OF SOUND With regard simply to the direction of the sound reflected from a surface, it is found to follow the same law as the reflection of light and heat, namely, that the path of the sound after reflection makes the same angle with the reflecting surface, if plane, as it did before reflection, and that these two directions and the perpendicular to the surface are in one plane If reflection take place from a curved surface, the direction of the surface at the point of impact may be represented by the tangent plane at that point Thu[illegible] body, as a bell, placed in the foc[illegible] [illegible]abolic mirror will give off vibrat[illegible] tions, those which stri[illegible] [illegible] axis; they m[illegible] on a second parab[illegible] [illegible]onjugate with the first, that is, having a common axis therewith, and [illegible] As in the case of light, spherical surfaces of small curvature may be substituted for parabolic ones, and then the sound emanating from the principal focus of one mirror (the point on the principal axis half way between the centre and centre of curvature), will be concentrated at the principal focus of the other mirror The curvature of the walls of many public buildings is such, that the sound of the voice when the speaker is near to one wall will be thus twice reflected, so that a person situated at a corresponding point near the opposite wall will hear the speaker distinctly, while those between the two, and therefore nearer to the speaker, will fail to do so Such is the action of whispering galleries, &c Echo is a familiar illustration of the reflection of sound If hands be clapped in the open air before a wall, a few yards off, two sounds will reach the ear, one the direct sound from the hands to the ear, the other the same sound, which is reflected from the wall before reaching the ear

As, however, the ear cannot distinguish between two sounds at an interval less than 1-16th of a second, these two sounds will be heard as one If the wall be about 35 feet away, the sound, to travel there and back, will have to pass through 70 feet, and this will take about 1 16th of a second, since sound travels at the rate of about 1100 feet per second Accordingly, the direct and reflected sounds will be heard distinct The further the wall is away the longer, of course, will the sound take to reach the ear after reflection In speaking several syllables in rapid succession the first may not yet have reached the ear before the last has quitted the lips And an echo is said to be monosyllabic, dissyllabic, &c, according to the number of syllables which can be uttered before the first returns An echo may also be "multiple"—that is, a single sound may give rise to a number of echoes Thus if a person stand midway between two parallel walls, A and B, and fire off a pistol, the report will strike the wall A, be reflected, and reach his ear at the same moment that the sound has reached his ear after reflection from B Further, the sound which reaches him from A will go past him and be reflected back by the wall B, and reach him at the same moment that the sound reaches him which has been reflected from B, thence to A, and thence to the auditor In short, with a loud report and smooth, vertical, and parallel walls, the echo of a single report may be very manifold It is clear, however, that those echoes which have been reflected most often will be the feeblest, having had to traverse the longest paths The continued noise produced in a room by a single loud report is due, in like manner, to the successive echoes from the walls, which are usually so near to one another that the separate sounds are blended Clouds are capable of producing echoes, as is often observed at sea when a gun is fired beneath a dense cloud Whenever refraction of sound occurs, as when a sound passes from a less dense to a more dense medium, reflection is always produced Hence it is that sounds are heard at a great distance when the air is of uniform density, as in the polar regions, and generally at night During the day the unequal heating of the earth and the continual ascent of watery vapour from different portions in vary-

ing quantity causes reflection to occur when the sound passes from one medium to another, and consequently a large portion of the undulations are dispersed

The speaking trumpet, speaking-tube, and ear trumpet are applications of the reflection of sound The first two confine the waves of sound by the reflecting power of their sides to a column of less diverging waves, the latter receives a large volume of sound waves, and, by reflection, concentrates them to the narrow end of the tube placed in the ear

REFRACTING TELESCOPE A telescope in which the principal image is formed by refraction through a convex achromatic lens, instead of by reflection from a concave speculum

REFRACTION, ANGLE OF See *Refraction, Index of*

REFRACTION, DOUBLE See *Double Refraction*

REFRACTION EQUIVALENTS Dr J H Gladstone gives the following table of the refraction equivalents of the elements (See *Refractive Energy, Specific*)

Aluminium,	8 4	Molybdenum,	10 4
Antimony,	24 5	Nickel,	
Arsenic,	15 4	Niobium,	
Barium,	15 8	Nitrogen,	4 1
Beryllium,	5 7	Osmium,	
Bismuth,	39 2	Oxygen,	2 9
Boron,	4 0	Palladium,	22 2
Bromine,	15 3, 16 9	Phosphorus,	18 3
Cadmium,	13 6	Platinum,	26 0
Cæsium,	13 7 (?)	Potassium,	8 1
Carbon,	10 4	Rhodium,	24 2
[illegible]		[illegible]	14 0
[illegible]		[illegible]	
Chlorine,	9 9, 10 7	Selenium,	[illegible]
Chromium,	15 9	Silicium,	7 5(?), 6[illegible]
Cobalt,	10 8	Silver,	13 5
Copper,	11 6	Sodium,	4 8
Didymium,	16 0	Strontium,	13 6
Erbium,		Sulphur,	16 0
Fluorine,	1 4	Tantalum,	
Gold,	24 0	Tellurium,	
Hydrogen,	1 3, 3 5	Thallium,	21 6 (?)
Indium,		Thorinum,	
Iodine,	24 5, 27 2	Tin,	27 0, 19 2
Iridium,		Titanium,	25 5 (?)
Iron,	12 0	Tungsten,	
Lanthanum,		Uranium,	10 8
Lead,	24 8	Vanadium,	25 3 (?)
Lithium,	3 8	Yttrium,	
Magnesium,	7 0	Zinc,	10 2
Manganese,	12 2	Zirconium,	22 3
Mercury,	21 3		

REFRACTION, INDEX OF When light passes obliquely from a rare to a dense medium it is refracted to a certain extent, varying with the medium employed, as the sine of the angle of incidence always bears an invariable ratio to that of the angle of refraction for the same ray and the same medium This ratio is called the *refractive index* of that medium This rule applies to gases as well as to solids and liquids (See *Refraction, Refractive Indices of Solids, Liquids, and Gases*)

REFRACTION INDICES OF OPAQUE BODIES. See *Opaque Bodies, Indices of Refraction of*

REFRACTION OF HEAT (*Frango*, to break up, allied to *ρασσω*)

Heat, like light, is capable of being refracted when it passes from a medium of one density into that of another—that is, the rays of heat, or lines in which the motion takes place, are diverted from their course on entering media, which vary from that which they leave When a convex lens is held in front of a source of light, we know that the light is refracted and brought to a focus on one side of the lens, and the same effect takes place in regard to heat, as is most simply shown with an ordinary burning glass The refraction of heat was well known to the ancients Aristophanes clearly alludes to the use of a glass lens for obtaining fire in the following passage from the *Nubes* —

Strepsiades ἤδη παρὰ τοῖσι φαρμακοπώλαις τὴν λίθον
ταύτην ἑώρας, τὴν καλήν, την διαφανῆ,
ἀφ' ἧς το πῦρ ἅπτουσι,

Socrates τὴν ὕαλον λέγεις;

Strepsiades ἔγωγε

Socrates φέρε, τι δῆτ' ἄν,

Strepsiades εἰ ταυτην λαβών,
ὁπότε γράφοιτο τὴν δίκην ὁ γραμματευς,
απωτερω στας ὧδε προς τον ἥλιον
τα γραμματ' εκτηξαιμι της ἐμης δικης

Pliny mentions that a glass globe filled with water was sometimes employed for concentrating the rays of the sun, and thus producing fire, and it occasionally happens now-a-days that a house is set on fire by the sun shining on a globe of gold fish, the focus of the concentrated rays having fallen upon muslin curtains or other inflammable substance Lactantius (*b* A D 250, *d* 320), in his treatise *De ira Dei*, states that fire may be kindled even in the coldest weather by means of a glass globe filled with water, and placed in the rays of the sun —"Orbem vitreum," he writes, "plenum aquae si teneris in sole, de lumine, quod ab aqua refulget, ignis accenditur etiam in durissimo frigore" Gunpowder has been ignited by a lens of ice, and B[illegible] constructed a liquid lens of considerable power, surpassed, however, by the great alcohol burning glass of Bernières and Trudaine, which was 3½ feet in diameter

The identity of the mode of refraction of heat and light is well illustrated by the prism [illegible] 1800, Sir William Herschel found that dark heat was refracted beyond the red end of the spectrum, and, more recently, Melloni, by using a prism of rock salt (which, unlike glass, [illegible] absorb dark heat), showed the refrangibility of heat by placing the thermopile [illegible] the source of heat, and [illegible] pile For more con[illegible] dark heat rays, see *Calorescence*

REFRACTIO[illegible]T When a ray of light passes obliquely from one transparent medium [illegible] another of different density, such as from air to glass, from glass to water, &c, it is refracted or bent out of its original course (See *Prism*, *Lens*, *Dispersion*) Some crystals possess the property of *double refraction*, which see

REFRACTION OF SOUND The rapidity with which sound diverges makes it very difficult to detect its concentration by refraction Sufficient evidence is, however, at hand to show that refraction does take place when sound passes from one medium to another of different density Thus, if a lens shaped bag of collodion be filled with carbonic acid gas, and a watch be placed on its principal axis on one side of the lens, the sound of the ticking will be heard loudest on the other side of the lens, at a point corresponding with the optical focus of the lens of similar shape of glass An ear trumpet placed about this spot will convey a louder sound to the ear than when placed nearer or further from the lens, or on one side of its axis A spherical bladder of carbonic acid shows the same effect distinctly, but less perfectly

REFRACTION, POLARISATION BY See *Polarisation Plane*

REFRACTION BY PRISMS See *Prisms*, *Spectroscope*, *Achromatic Prism*

REFRACTION, UNUSUAL Under this name Brewster (Optics, p 255), has classed several phenomena of refraction, caused by light passing through atmospheric strata of different local densities, owing to local heat or cold In some cases at sea, an inverted image of a ship is seen beneath the real ship, and, in other instances, when the greater part of a ship is below the horizon, two complete images of the ship have been seen above it in the air The appearances known as *looming*, *mirage*, *fata morgana*, are phenomena of unusual refraction

REFRACTIVE ENERGY, SPECIFIC Gladstone and Dale have found that the refractive index of a substance, minus unity, multiplied into the volume, gives very nearly a constant product at different temperatures This product is called the specific refractive energy The specific refractive energy of a mixture is the mean of the specific refractive energies of its components (See *Refraction Equivalents, Table of*)

REFRACTIVE INDICES OF GASES

Name of Gas	Index of Refraction	Name of Gas	Index of Refraction
Air, . . .	1 000294	Cyanogen, . .	1 000834
Oxygen, . .	1 000272	Marsh Gas,	1 000443
Hydrogen, . .	1 000138	Hydro cyanic Acid,	1 000451
Nitrogen, . .	1 000300	Ammonia, . .	1 000385
Chlorine, .	1 000772	Phosgene,	1 001159
Hydro chloric Acid,	1 000449	Sulphuretted Hydrogen,	1 000644
Carbonic Oxide, .	1 000340	Sulphurous Acid,	1 000665
Carbonic Acid, .	1 000449	Phosphuretted Hydrogen,	1 000789

REFRACTIVE INDICES OF LIQUIDS

Name of Liquid	Index of Refraction for mean yellow ray	Name of Liquid	Index of Refraction for mean yellow ray
Phosphorus in Disulphide of Carbon, .	1 952	Ether, .	1 358
Disulphide of Carbon,	1 678	Alum, Sat Sol .	1 356
Oil of Cassia, .	1 631	Water, .	1 336
Bitter Almond Oil, .	1 603	Methylic Alcohol, .	1 330
Nut Oil, . .	1 500	Iodide of Ethyl, .	1 500
Linseed Oil, . .	1 485	Acetic Acid, .	1 371
Rape Oil, . . .	1 475	Chloroform, .	1 446
Olive Oil, . .	1 470	Benzol, . .	1 497
Oil of Turpentine, . .	1 470	Nitro benzol, .	1 546
Oil of Lavender, .	1 457	Aniline, .	1 578
Chloride of Sodium, Sat Sol	1 575	Glycerine, .	1 470
Alcohol, . .	1 372	Nitro-glycerine, .	1 475
		Nicotin, . .	1 523

REFRACTIVE INDICES OF SOLIDS

Solid Substance	Index of Refraction for mean yellow ray	Solid Substance.	Index of Refraction for mean yellow ray
Chromate of Lead,	2 50 2 97	Rock Salt, . .	1 545
		Sugar, . .	1 535
renecto[illegible]	2 47	Phosphoric Acid, .	1 534
instances they monsght	Now, as thermometers were not yet invented,	[illegible]lam, .	1 532
they are[illegible]us,	[illegible] of the mirror, [illegible] is not sufficie[illegible]		1 527
Sulphur, .	2 115	Crown Glass, focus [illegible]	1 525 [illegible]
Zircon,	1 950		
Borate of Lead,	1 866	Plate Glass,	1 514 1 542
Ruby, .	1 779		
Felspar, .	1 764	Iceland Spar,	1 654
Tourmaline,	1 668	Obsidian, .	1 148
Topaz, .	1 610	Borax, .	1 475
Beryl,	1 598	Alum, .	1 457
Emerald, .	1 585	Fluorspar, .	1 436
Flint Glass,	1 575	Ice, .	1 315
Rock Crystal,	1 547	Tabasheer,	1 111

REFRACTIVE POWER OF THE ATMOSPHERE As the atmosphere diminishes in density as its distance from the earth increases, it follows that rays of light passing diagonally through it are bent out of their course This bending is sufficient to cause objects which are really below the horizon to appear above it Owing to this cause, an eclipse of the moon has been seen by the writer when both the sun and the moon were visible above the horizon The refraction of the atmosphere is of importance in astronomical observations, and must be corrected or allowed for When there are layers of air of different temperatures and varying densities, rising and falling irregularly, refraction takes place, which interferes with distinct vision (See *Refraction*)

REFRANGIBILITY (*Re* and *frango*, to bend) The property which rays of light and heat possess of being bent out of a straight line when they pass from one medium to another of different density

REGELATION (*Regelatio*, thawing) It seems probable that Faraday, who gave this name to the phenomenon we are now to describe, supposed "*regelatio*" to signify re freezing When two pieces of melting ice are brought into contact congelation takes place when they touch This phenomenon, first noticed by Faraday, is called *regelation* He explained it on this wise The particles at the surface of a mass of ice are less restrained by the force of cohesion than those within the mass Thus they pass easily into the liquid state, and accordingly the surface of ice, when the temperature is near the freezing point, becomes moist Now, when two pieces of ice in this condition are brought into contact, those particles which are upon the surface, brought together, are placed in the condition of particles belonging to the inside of a mass of ice, and being thus brought more fully than before under the influence of the force of cohesion pass into the solid state When the temperature is below the freezing point regelation does not take place, for the surface of the ice continues dry at such temperatures

REGULATOR. (*Regulator*, from *regula*, a rule , *regulare*, to adjust by rule) Any

contrivance for securing uniform motion with a variable power or resistance in machines It is frequently the case that one or more of the elements of motion are essentially variable, as the uncoiling of the mainspring or the descent of the weight in timepieces, the action of the connecting-rod on the crank in the steam-engine, the pressure of the steam in the cylinder, &c. In all these cases uniform action may be obtained by a suitable arrangement of the machinery by which the force is transmitted to its point of application This is the purpose served by the contrivances known as the fusee, pendulum, fly-wheel, governor, for which see articles under those headings, also *Horology*, and *Engine*

REGULUS (Little king) The star α in the constellation Leo, called also *Cor Leonis*, the lion's heart

RELATION OF MUSIC AND SOUND See *Harmony*, *Melody*, *Musical Intervals*

RELATIVE PHOTOMETER See *Photometry*

RELAY See *Telegraph*

RESIDUAL CHARGE See *Charge, Residual*

RESINS A name given to many vegetable substances which are allied physically, although they may differ chemically They are insoluble in water, and generally soluble in alcohol and essential oils They soften or melt with heat, do not crystallise, are of different shades of yellow or brown, and are of various degrees of transparency They are of considerable commercial value for the manufacture of soap, varnish, benzoic acid, &c The following are some of the principal resins —Benzoin, dragon's blood, Peru balsam, storax, Tolu balsam, gum ammoniacum, anime, asafœtida, copaiba, copal, dammar, elemi, galbanum, gamboge, guaiacum, lac, mastic, myrrh, olibanum, sandarach, scammony, turpentine The following are fossil resins —Amber, asphalt, fossil caoutchouc, peat resins, pyroretin, retin asphalt, tasmannite

RESISTANCE Any force which prevents a body moving when other for[illegible] upon it, or which is oppose[illegible] friction, the rigidit[illegible] that off a moving bo[illegible] called into pla[illegible]ces, are termed *passive* resistances (See *Action and Reaction*)

RESISTANCE COILS In measuring the electric resistance of wires it is necessary to have standards of resistance of known and various magnitudes wherewith to compare it The standards generally used in this country are coils of copper or German silver wire, accurately cut off, so that the resistance of each is a multiple of the British Association Unit of Electric Resistance (See *Units, Electrical*) For convenience they are generally placed in a box, and joined to studs of brass which come to the outside of the box, and by means of which the coils can be connected together so that the current may be sent through any number of them at pleasure, and on the studs are marked the numbers which represent the quantities of resistance introduced when its coil is thrown into the circuit A convenient resistance box may contain altogether 10,000 B A Units, arranged so that any number from 1 to 10,000 may be introduced Thus the numbers may run 1, 2, 2, 5, 10, 20, 20, 50, 100, 200, &c, 5000, as in a decimal system of weights

RESISTANCE, UNITS OF See *Units, Electrical*

RESISTANCE OF A CONDUCTOR The following description of an experiment will explain what is meant by the resistance of a conductor —Let the terminals of a battery be connected with a tangent galvanometer (see *Galvanometer*) by means of short, thick wires, and let the deflection be noted Then let twenty or thirty yards of moderately fine wire be introduced into the circuit, so that the current shall have to pass through it, it will be found that the deflection of the needle is very much diminished, showing that the quantity of electricity passing is smaller than before Now, let another twenty yards of wire be introduced, the current will become still weaker On removing the thin wire from the circuit, and again connecting the battery by short, thick wires with the galvanometer, the original deflection will be obtained if the battery be constant It appears, therefore, that, although the metallic wire conducts the current, nevertheless the introduction of a long, thin wire very much decreases the strength of the current, and the longer the wire the greater this diminution, and since we know that the strength of the current is the same at all parts of the circuit, and that, therefore, the phenomenon does not arise from anything of the nature of loss by the way, we consider that the current is prevented from flowing by the resistance which the wire offers to its passage

The laws of electric resistance have been carefully determined, and very accurate numerical results have been obtained, the subject being of the very highest practical as well as theoretical importance It is found that by using wires of the same material the resistance is in simple proportion to the length—that is, a wire two or three feet long gives twice or thrice the resistance that a wire one foot long would give, under similar circumstances, the resistance is inversely proportional to the section of the wire—that is, the greater the section the smaller the resist-

ance, and the finer the wire the greater the resistance Also the resistance depends upon the material of which the wire is made Resistance is, in fact, want of conductivity We have given under *Conductor* numbers expressing the conducting power of metals The following list by E Becquerel expresses the *specific resistance* of metals, the resistance of copper being taken as unity—that is to say, the resistance of a certain length of pure copper wire of a given diometer being taken as unity, the following numbers express the resistance of wires having that diameter —

RESISTANCE OF METALS. TEMPERATURE, 54° F (12 2° C)

Copper,	1 0	Tin,	6 6
Silver,	0 9	Iron,	7 5
Gold,	1 4	Lead,	11 0
Zinc,	3 7	Platinum,	11 3

Mercury, 50 7 at 57° F (13 8° C)

The resistance of metals is very much altered by the occurrence of the slightest impurity in them, for example, the resistance of pure copper wire is increased by 25 per cent by the admixture of ⅛th per cent of iron, and a very minute quantity of arsenic may raise it as much as 50 or 60 per cent Matthiessen has made an enormous number of determinations of conductivity, and has published the results in the Reports of the British Association Committee on Standards of Electrical Resistance (See B A Reports from 186 and in particular those of 1863 and 1864) Resistance depends also on the molecular condition of the wire, thus it is decreased by annealing and increased by hardening, or by hammering or twisting. It is also influenced by the temperature of the metal All metals lose conductivity—that is, increase in resistance—on being heated Between 32° F (0° C) and 21 ienecte C) some metals lose as much as 30 per cent of their conductivity instances they monsght rrow, as thermometers were not yet invented, cases very great as com they are that of solid conductor of the minor, was not sufficient by E Becquerel, comparing the conductivity of saturated solutions with that of silver focus oare of a saturated solution of chloride of sodium (common salt) the resistance is about 3,000,000 times as great as that of silver, in the case of distilled water it is expressed by the enormous number 7,000,000,000

In expressing resistances, it is now usual to state them in terms of the unit of electrical resistance adopted by the British Association for the Advancement of Science (See *Units, Electrical*) Thus to state the electrical conductivity of a wire or a specimen of metal it is said that its resistance is so many B A units per gramme per metre (or per grain per foot)—that is to say, that the resistance offered by a wire of the metal in question one gramme in weight and one metre long is expressed in B A units by the number given

From the laws we have laid down above, and the numbers we have given, it is easy to calculate the absolute resistance of a given specimen of wire of any material, length, and diameter, knowing that one mile (5280 feet) of pure copper wire, 0 2302 of an inch in diameter, has a resistance of one British Association unit For if R express the resistance in B A units, l the length in feet, and d the diameter in inches, then evidently

$$R = \frac{l}{5280} \times \left(\frac{0\ 2302}{d}\right)^2 = 0\ 000010036 \frac{l}{d^2}$$

RESISTANCE OF GASES TO MOVING BODIES It is found by experiment that when a flat surface moves through the air, or other gas, in a direction perpendicular to the surface, the resistance it experiences is nearly directly proportional to the size of the surface For surfaces of the same size, the resistance is found to vary as the square of the velocity Hence, when a body falls from a great height, so that in vacuo it would acquire a very great velocity, it is often found that the resistance of the air has been so increased by the velocity that a uniform velocity has been attained It follows also that in falling through air large bodies will fall faster than smaller ones of the same shape and of the same material For the mass varies as the cube, while the surface upon which the air exerts its resistance only varies as the square of the linear dimension, so that there is a greater ratio between the two in the case of small than in that of large bodies For the same reason, a sheet of paper will fall more quickly when rolled up into a ball than when extended. In the former case the surface of resistance is the horizontal projection of the paper pellet.

RESISTING MEDIUM See *Medium, Resisting*

RESOLUTION OF FORCES (*Resolvere, Resolutum*, from *re*, again; *solvere*, to loosen) The operation of substituting for a single force acting upon a body two or more forces which, conjointly, shall produce the same effect as the original force. (See *Parallelogram of Forces*)

RESOLVABLE NEBULÆ. See *Nebulæ*.

RESONANCE The loudness of the sound produced by a sounding body is augmented by bringing the body into the neighbourhood of a column of air which is capable of vibrating in unison with the body Thus, a tuning fork which makes say 100 complete vibrations in a second, is held over a wide telescopic tube made of card board, and open at both ends, the sound of the fork will be increased when the telescopic tube has a certain length, and then only In the instance taken, the wave length of the note is $\frac{1100}{100}$ feet, or 11 feet The length of the column of air which gives, as a fundamental note, the note corresponding to a given wave length, is half that wave length, here therefore, 5 ft 6 in , and this is the length of the open tube, the air in which resounds to the note of the fork If the tube be closed at one end, it will have to be half this length, or 2 ft 9 in A tubo whose length is any simple multiple of this length will also augment the sound, resounding to the fork, because nodes will be formed in it in such a manner as virtually to divide it into segments The tube as a whole will no longer give its fundamental note, but an octave or other simple harmonic thereof Instead of being directly communicated to the air of the column, the vibrations of the fork may be communicated, in the first instance, to a solid Thus, the intensity of the sound of a fork is increased by screwing it on to a box closed at one end, whose length is ¼ the wave length of the fundamental n[illegible]e of the fork In the guitar, violin, &c , the vibrations of the string are communicated thr[illegible]gh the bridge and through the "sound column" (a pillar connecting the back and front of t[illegible] instrument) to the air in the inside The irregular form of the instrument offers a great v[illegible]ety of lengths of air columns, one or more of which resounds to every note of the strings The sounding board of a *pianoforte* not only conveys an additional amount of the string's vibrations to the air, but also to the other strings which are thereby set in motion if their rates of vibration are simply commensurablo with that of the original note The hollow of the m[illegible] [illegible]as a resonance chamber for the au[illegible] of the sounds of the vocal chords [illegible] [illegible]sed on noting the char[illegible] different pitch

RES[illegible] ([illegible]*re*, again , and *spiro*, to breathe) Under the heading *Animal Nutrition*, we have explained how the food after digestion and absorption into the circulation, is partially burnt into carbonic acid and water by the action of the oxygen contained in the atmosphere Every time an animal inspires, air is taken into the lungs, where it is exposed to an enormous surface of blood-vessels, by which it is chemically absorbed, producing oxidation, and supplying the necessary amount of force for the body This action is called respiration (See also *Animal Heat*, *Food*, *Functions of*)

RESULTANT (*Resultare*, to leap back) A term applied to any force which will have the same effect as two or more given forces (See *Parallelogram of Forces*, *Parallel Forces*)

RETICULUM (Abbreviated from *Reticulum Rhomboidale*, the Rhomboidal Net) One of Lacaille's southern constellations

RETINA (*Rete*, a net) The innermost coating of the eye, consisting of an expansion of the optic nerve in the form of a net (See *Eye*)

RETORT (*Re*, back , and *torqueo*, to turn) A vessel in which a substance is placed for the purpose of submitting it to distillation.

RETROGRADATION In astronomy the apparent motion of a planet in a direction contrary to the order of the signs The superior planets appear to move retrogressively when they are in or near opposition, because the earth is moving more quickly forward, and so seems to leave them behind On the other hand, the inferior planets appear to move retrogressively when they are in or near inferior conjunction, because they are then between us and the centre of motion

RETROGRADE (*Retro*, backwards , and *gradus*, a step) The motion of a planet in a direction contrary to the order of the signs

RETURN STROKE When a thunder cloud approaches any locality all the ground beneath it and around it becomes oppositely charged, owing to inductive action taking place between the cloud and the earth , and in particular, any prominence, such as a tree, or a man, or animal standing out on a plain, sustains this inductive charge to a very high degree Suppose now that a discharge takes place between the cloud and the ground at a long distance, perhaps a mile or more from the object of which we are speaking, suddenly the electricity of the cloud is neutralised , the electricity which was before held bound in the object by induction becomes free, and rushes back to the earth, causing a violent commotion which is known by the name of the *return stroke* or *back stroke* The effects, though not so powerful as those of the discharge, are yet frequently very violent There are many cases in which men and animals have been killed by it When death occurs on account of it, there is never any wound, burn, or inflammation, nor are the effects made visible by any spark. The many cases in which people are

thrown down uninjured, and suppose themselves to have been struck by lightning, are evidently due to the return stroke

It may be felt to a slight degree by standing close to a Winter's machine with the large ring on the prime conductor, while sparks are being drawn from it, or may be imitated by placing a frog near to it, at each passage of a spark, a lively commotion is felt

REVERSAL OF SODIUM SPECTRUM See *Fraunhofer's Lines, Artificial*

REVERSING PRISM. See *Right-angle Prism*

RHEOMOTOR (ῥέω, to flow) An arrangement, such as a cell or battery, which gives rise to an electric current The name *electromotor* is more frequently used

RHEOSCOPE (ῥέω, to flow, σκοπέω, to see) An instrument for detecting the existence of an electric current

RHEOSTAT (ῥέω, to flow; ἵστημι, to place) An instrument invented by Sir Charles Wheatstone for putting a known resistance into a galvanic circuit and thus regulating the current's strength It is used in making measurements of electric resistances Two equal cylinders, one of wood, which we shall call A, the other of brass, which we shall call B, are arranged on parallel axes side by side The wooden cylinder A, has a spiral groove cut in it, and a long fine copper wire is arranged between them so that on turning a handle it is wound off one on to the other When any quantity of it is wound on to A, it lies in the spiral groove, and thus the coils are insulated from each other Any portion of it that is wound on B is in contact with the metal cylinder, and completely uninsulated one part from the other There are two binding screws, one connected with each end of the wire If the instrument be put into a galvanic circuit, any given quantity of the resistance of the wire can, with readiness, be thrown into the circuit For it is only necessary to wind the required amount off the brass cylinder on to the wooden [illegible] as this portion of wire is then insulated [illegible] from every other, the cur[illegible] [illegible] part on the brass [illegible] then no farther resistance [illegible] along the brass goes at once to the binding screw To decrease the resistance it is only [illegible] wire off the wooden cylinder on to the brass one An index is attached to the axis of the wooden cylinder to tell how much wire is wound upon it

RHEOTOME, or *Current-Break* (ῥέω, to flow, τέμνω, to cut) A piece of apparatus used in connection with arrangements for obtaining induced currents to produce temporary currents in the primary wire There are several forms, a very simple one may be made by attaching one of the battery wires to a common rough file, and then drawing the other along the teeth, every time the wire leaves a tooth, the current is stopped A more convenient one may be made by attaching one wire to a toothed wheel which can be turned with a handle, and the other to a spring which touches the teeth, the current, as before, being stopped during the passage of the spring from one tooth to another Other forms of rheotome which belong to particular induction arrangements are described in their proper places

RHODIUM (ῥόδον, a rose) A metal occurring in very small quantities in platinum ore, it was discovered by Wollaston in 1804 It is a grayish-white hard metal, scarcely fusible before the oxyhydrogen blowpipe Specific gravity 12 1 Atomic weight 104 Symbol Rh It is not altered by exposure to air or moisture, but at a red heat is converted into oxide Its compounds are unimportant

RHOMB, FRESNEL'S An instrument for converting plane into circularly polarised light It consists of a parallelopiped of crown glass having two acute angles of about 54° and two obtuse angles of 126° If a ray of plane polarised light enters perpendicularly at one of the ends, it suffers double reflection from the two interior opposite surfaces and emerges at the other end circularly polarised (See *Polarised Light*)

RHUMBS The nautical name for the thirty-two points of the compass. (See *Points of the Compass*)

RIGEL (Arabic) The star β of the constellation Orion A noted double star

RIGHT-ANGLE PRISM A prism, usually of glass, the section of which at right angles to the axis is a right-angle triangle, the two sides enclosing the right angle are generally of equal length When a ray of light enters one of the sides perpendicularly to it, it suffers total reflection from the interior surface of the hypothenuse and emerges from the opposite side, the ray being bent 90° from its original path without suffering refraction When the ray of light enters the prism parallel to the hypothenuse, it is refracted to that surface, then totally reflected to the opposite side, and is again refracted on emerging, so that its original direction is preserved, and as the two refractions neutralise each other, there is no dispersion Owing to the single reflection which it suffers, the pencil of light is inverted, and, therefore, objects viewed through a reflecting prism in this direction appear in their right places, but with their sides reversed. Used in this manner, a right-angle prism is sometimes called a *reversing prism*. As

the reflection is total, and there is no metallic surface to get tarnished or injured, right-angle prisms are largely used in philosophical instruments as reflectors (See *Prism*)

RIGHT ASCENSION See *Ascension, Right*

RIGHT-ASCENSION CIRCLE See *Hour Circle*

RIGHT HANDED AND LEFT-HANDED POLARISATION If a slice of quartz cut perpendicularly to the axis of the crystal be examined in the polariscope, no black cross will be seen, as in the case of calc spar, and, on rotating the analyser, the colours will not alternately appear and disappear, but there will be apparent a system of rings, with a coloured disc in the centre, which pass through all the colours of the spectrum If the analyser has to be turned towards the right, so as to cause the colours to succeed each other in their natural order—red, orange, yellow, green, blue, indigo, violet—the piece of quartz is called *right handed,* or *dextro-gyrate* If, however, the analyser has to be turned from right to left to obtain the natural order of colours, the quartz is called *left-handed* or *lævo-gyrate*, the two kinds of polarisation being respectively called right handed circular polarisation and left handed circular polarisation An examination of the crystalline form of the quartz will in some cases show whether it is dextro- or lævo-gyrate Many liquids possess this property of circularly polarising light (See *Circular Polarisation of Liquids , Polarised Light*)

RIGHT-HANDED AND LEFT HANDED TARTARIC ACID A method [illegible] eparating these two bodies has been published by M Gernez, based upon the phenomena of supersaturation He finds that a supersaturated solution of left handed double tartrate of soda and ammonia does not crystallise in contact with a fragment of the same salt, but of the right-handed variety, and *vice versa* From a supersaturated solution of inactive double racemate of soda and ammonia, a fragment of right handed crystal determines only the [illegible] on of right-handed crystals , whi[illegible] of the sa[illegible] in contact [illegible] produces a depo[illegible]

RIGIDIT[illegible] [illegible]idus, stiff or numb , Greek, *ῥίγειν*, to shudder or shiver with cold , Th[illegible] [illegible]ing change of form, the opposite to flexibility Rigidity is expressed by means of a quantity called a *modulus*, or *co efficient of rigidity*, by taking the ratio of the intensity of a given stress of a given kind to the strain, or alteration of figure with which the stress is accompanied Hence—

Modulus of rigidity = intensity of stress — strain

The *strain* in this equation is expressed as a quantity by dividing the alteration of some dimension of the body by the original length of that dimension In most substances which are used in construction, the moduli of rigidity, though not exactly constant, are nearly constant for stresses not exceeding the proof strength The rigidity of ropes plays an important part in relation to the work of the machines in which they are used, especially of the wheel and axle, and the pulley It is necessary, therefore, in machinery to be able to estimate in given cases the extent of the resistance from this cause When a power and a weight act at opposite extremities of a rope passing over a pulley, the friction between the rope and the pulley being sufficient to cause the latter to rotate, it is evident that the rope is bent into an arc In consequence of the resistance offered by the want of flexibility, an additional force has to be applied to make the pulley revolve In experimentally determining the amount of resistance due to rigidity, not only the radius of the pulley must be considered, but also the radius of the rope, and the forces are considered to act along the axis of the rope, that is, at a distance from the centre of the pulley equal to half the sum of the diameters of the pulley and the rope This is called the effective radius of the pulley or drum By actual experiment it is found that one portion of the resistance depends solely on the rope itself, and another portion is related to the intensity of the weight acting on the pulley Again, other things being equal, the resistance due to rigidity is greater as the curvature imparted to the rope increases The table given below contains the results of Morin's calculations from Coulomb's experiments, and relates to the following rule for obtaining the resistance offered by ropes in consequence of their rigidity —Multiply B by the weight in lbs , add the product to A , and divide the sum by the effective radius of the pulley in inches, the quotient gives the resistance in lbs Thus when the weight is 500 lbs , and a new dry rope, 3 inches in circumference, is used to lift it, and passed round a pulley 11 inches in diameter, the resistance due to rigidity is 30 lbs , and the result is the same as if 530 lbs were raised over a pulley of 12 inches in diameter by a perfectly flexible string It will be seen by the table how much faster the resistance due to rigidity increases than does the radius of the rope used , also that the resistance is less for tarred ropes (except very thin ones) than for new dry ropes of the same radius When a rope is wound on or off a drum, we consider the rigidity only in winding on the drum , it is not called into play in unwinding For investigations of this subject, see Young's *Natural Philosophy*, vol. ii. p. 271, for abstract of Coulomb's labours, and Morin's *Notions Fondamentales*, pp 316-332

RIGIDITY OF ROPES

Radius of Rope	Circumf of Rope	New Dry Ropes		Tarred Ropes	
		A	B	A	B
0 16 in	1 in	0 32	0 034910	0 41	0 028917
0 24	1 5	1 43	0 078543	1 44	0 065068
0 32	2	4 31	0 139640	3 86	0 115668
0 40	2 5	10 31	0 218183	8 64	0 180731
0 48	3	21 13	0 314190	17 03	0 260253
0 56	3 5	38 87	0 427643	30 56	0 354233
0 64	4	66 00	0 558560	51 05	0 462672
0 72	4 5	105 38	0 706723	80 08	0 585569
0 80	5	160 23	0 872750	121 50	0 722945

NEBULÆ See *Nebulæ*

S, NEWTON'S See *Newton's Rings*

S OF SATURN See *Saturn's Rings*

HIE'S PHOTOMETER This photometer is somewhat similar to Bunsen's Light from each source is reflected upon the two halves of a sheet of oiled paper, and the lights are moved until the illumination of each half appears the same. The intensities are then as the squares of the distances from the oiled paper.

ALT See *Tartaric Acid*

distances they mongst. Now, as thermometers were not yet invented, ... they are ... of the mirror. ... not suffic... focus ...

ROCK-SALT See *Sodium, Chloride*

ROSANILINE, or, *Aniline Red* See *Aniline.*

ROSEINE See *Aniline*

ROTATION OF THE EARTH See *Earth*

ROTATORY POLARISATION See *Circular Polarisation*

ROTATORY POWER, SPECIFIC See *Specific Rotatory Power*

RUBIDIUM (ρυβιδος, dark red) A metal belonging to the alkali group, occurring with cæsium, and discovered by Bunsen and Kirchhoff by means of spectrum analysis Its spectrum contains two dark red lines less refrangible than the line A of the solar spectrum In the metallic state, rubidium is very similar to potassium Its specific gravity, however, is 1 52 Atomic weight, 84 5 Symbol, Rb

RUBY See *Corundum*

RUHMKORFF'S COIL See *Induction Coil*

RUMFORD'S PHOTOMETER This photometer is easily extemporised A ruler, or even the finger, equidistant from the two sources of light, is held against a sheet of white paper, so that the two shadows thrown by the lights are close together The darker shadow being thrown by the strongest light, the distances between the lights are varied until the shadows are equal, their intensities are then to each other as the squares of the distances (See *Photometry*)

RUTHENIUM A very rare metallic element occurring in platinum ore, and somewhat resembling rhodium, but even more infusible Specific gravity, 11 4. Atomic weight, 1 04. Symbol, Ru Its compounds are unimportant.

RUTILE. See *Titanium, Dioxide.*

S

SACCHARIC ACID An acid produced by the action of nitric acid on sugar Formula, $C_6H_{10}O_8$ It is not crystallisable, is deliquescent, readily soluble in water and alcohol, and forms crystalline salts with bases

SACCHAROMETER, OPTICAL (σακχαρ, sweet, and μετρέω, to measure) An instrument for determining the amount of cane sugar in a liquid, depending on the phenomena of polarised light (See *Circular Polarisation of Liquids, Right-handed and Left-handed Polarisation*) It consists of a polariscope so arranged that a tube about ten inches long, closed at each end with a plate of glass, may be interposed between the polariser and analyser in such a manner that the whole column of liquid may be traversed by the ray of light. A solution of sugar or cane juice, the strength of which it is desired to estimate, is decolourised, when necessary, by animal charcoal, and introduced into the tube. The analyser having been turned until the field is black, and the index attached to it is at zero, the introduction of the sugar solution will

cause colour to be visible, the analyser is then rotated until a certain standard tint is produced. The angle of rotation is then compared with the angle through which the analyser has to be turned to produce the same effect when a solution of perfectly pure cane sugar of known strength is examined in the tube As the determination of the standard tint is a matter of some little difficulty at first, the device is employed of interposing a red glass, coloured with oxide of copper, which only allows the red rays to pass On rotating the analyser, the field now becomes alternately red and black, owing to the other colours being unable to pass through the glass All that is necessary now is to measure the angle through which the analyser has to be turned to bring this red ray into the field. Pure cane sugar is strongly right handed, whilst the uncrystallisable sugar obtained by the alteration of cane sugar by heat, or the action of acids, is left-handed In sugar refining it is of the utmost importance to prevent the cane sugar being changed by too long boiling, or by the accidental presence of an acid, and the optical saccharometer has been found of value by giving timely warning of the approach of injury from these causes In practice the instrument has many refinements and modifications, tending to simplify the observations, and make them more accurate One of the forms of saccharometer now most in use is that devised by Soleil, and improved by Duboscq, it is not, however, an altogether satisfactory instrument (See *Polarised Light, Polariscope, Circular Polarisation*)

SADALMELIK (Arabic) The star α of the constellation Aquarius

SADALSUND (Arabic) The star β of the constellation Aquarius

SAFETY LAMP See *Lamp, Safety*

SAFETY VALVE In the steam engine an apparatus to secure the escape of the steam when it exceeds a certain pressure It usually consists of a plug, fitting the top of a short tube opening into the boiler, which is attached to a lever The other end of the lever i [illegible] wn either by a weight or by a spr[illegible] pressure on the valve may be [illegible] weight along the le[illegible] in the the pressure exe[illegible]ver the valve rises, and the steam escapes Frequently the valve is co[illegible] into the top of a steam dome fixed on to the boiler Frequently in stationary engines, and always in locomotives, there are two safety valves, one under the control of the engineer, and the other entirely enclosed (See *Steam-Engine*)

SAGITTA (The arrow) One of Ptolemy's northern constellations. It is the least of all the ancient constellations

SAGITTARIUS (The archer) A sign of the zodiac The sun enters this sign on about November 22d, and leaves it on about December 21st The constellation Sagittarius occupies the zodiacal space corresponding to the sign Capricornus It is represented under the figure of a centaur, bearing a bow, and about to shoot

SAINT MARTIN'S SUMMER The name popularly given to that mild damp season which commonly prevails from November till about Christmas time It is due to the prevalence of south westerly winds

SAL AMMONIAC See *Ammonium, Chloride of*

SALICIN An organic substance contained in the bark of the willow It forms white crystalline tables, soluble in water and alcohol Formula $C_{13}H_{18}O_7$ It is decomposed when heated above 200° C (392° F)

SALICYLIC ACID An organic acid which exists ready formed in some plants (in the flowers of the *Spiræa Ulmaria*, for instance), and may be prepared artificially by the oxidation of salicin, it dissolves in water, and crystallises easily in large four sided prisms, which melt at 150° C (302° F), and sublime at about 200° C (392° F), without decomposition It unites with bases, forming a well crystallised series of salts called *salicylates*

SAL PRUNELLÆ See *Nitrates, Nitrate of Potassium*

SALT This term was originally applied to chloride of sodium, or common salt As chemistry advanced it was seen that other substances were strictly analogous in composition, &c to chloride of sodium, such as sulphate of soda, and nitrate of potash, and they were therefore called salts A little further progress of chemistry led to the definition of a salt as a neutral substance, formed by the union of an acid and a base But this definition, although it applied perfectly to sulphate of soda, which is made by neutralising sulphuric acid with the base soda, would not apply to chloride of sodium, which contains neither acid nor base, but only the two elements chlorine and sodium The incongruity of refusing the title of salt to chloride of sodium soon led to another theory of salts, the theory that a salt consists of an electro negative body with an electro-positive body, the first class being *haloid* salts, and the second class being *amphid* salts (See *Haloid*) After discussion however showed that this distinction was somewhat arbitrary and unnecessary, and the binary theory was introduced, by which the two classes were fused into one, and all salts were supposed to be built up on the type of chloride of sodium, sulphate of soda being supposed to consist of sodium and a hypothetical radical

containing sulphur and oxygen, analogous to chlorine This theory now appears to have gone the way of the others, and chemists have no good definition of the term *salt, acid*, or *base* The fact appears to be that these terms are convenient in ordinary chemical language, and are, with few exceptions, perfectly well understood by chemists, but the finer distinctions between either of them, and some other substances which have no claim to these titles, cannot be accurately defined, and until this is done, a scientific definition which shall meet all cases, and admit of no exceptions, is an impossibility Like the colours of the spectrum, it is easy to say that one is red and another yellow, but it is impossible to give such an accurate definition of these terms as will enable any one to say where one ends and another begins

SALT, COMMON See *Sodium Chloride*

SALTPETRE See *Nitrates, Nitrate of Potassium.*

SAMIEL The Turkish name for the *sirocco* (*q v*)

SANDARACA See *Arsenic, Sulphides of*

SAPONIFICATION Originally this term was employed to express the decomposition of fats, under the influence of alkalies, into glycerin and a fatty acid which uniting with the alkali formed soap It is now extended to all analogous actions in organic chemistry (See also *Soap*.)

SAPPHIRE See *Corundum*, and *Aluminium.*

SATELLITES (*Satelles*, an attendant) The name given to those secondary bodies which revolve around some of the planets The elements of the known satellites will be found under the head *elements*, and further information under the heads *Moon*, *Lunar Theory*, *Jupiter*, *Saturn*, &c , *Nebular Hypothesis*, &c.

The relation of the satellites to the solar system is, in some respects, peculiar Our own moon [illegible] more nearly resembles the primary orbs [illegible] any of the other satellites, [illegible] are to accept the present estimates of the density and mass of Jupiter's satellites, [illegible] regard these bodies as differing very remarkably in structure from Mars or Mercury, [illegible] or even from the less substantial, though more massive fabric of their primary and his fellow giants One of them has a mean density only one-ninth of that of water, or less than half that of cork, while even the densest has a specific gravity of only 0 396, that of water being taken as unity It will be seen under head *Elements*, that the planets of lightest substance are yet far more substantial than this We know nothing as to the density of Saturn's satellites, but it is not unreasonable to conclude that they are related to their primary in much the same way as the satellites of Jupiter to theirs

It has been supposed, from observations made by Sir W Herschel, that the satellites of Jupiter keep always the same face turned towards their primary, but modern observations render this view more than doubtful

SATURATION In chemistry, a liquid is said to be saturated with a solid, liquid, or gas which it is capable of dissolving, when it has taken up as much as possible An acid is said to be saturated when a sufficient amount of base is added to it, to form a neutral salt and *vice versa* in the case of a base (See also *Solution*, *Supersaturation*)

SATURATION In meteorology, the air is said to be saturated with aqueous vapour when no more vapour can be added without condensation taking place At a given temperature, the air will retain a definite quantity of aqueous vapour in the invisible form, the quantity being independent of the density of the air, and in fact the same—space for space—as though there were no air With increase of temperature the quantity of aqueous vapour which can be retained in the invisible form increases, but not in the same proportion The following table (abbreviated from Mr Glaisher's Hygrometric tables) shows the elastic force of vapour (measured by the height of mercury it would support) corresponding to different temperatures from 0° to 80° Fahrenheit —

Temp	Force of Vapour	Temp	Force of Vapour	Temp	Force of Vapour
	Inch		*Inch*		*Inch*
0°	0 044	30°	0 167	60°	0 518
5	0 054	35	0 204	65	0 617
10	0 068	40	0 247	70	0 733
15	0 086	45	0 299	75	0 868
20	0 108	50	0 361	80	1 023
25	0 135	55	0 433		

It will be seen that the increase of force takes place at a greater rate than the increase of

temperature For instance, the tension is increased by 0 042 as we pass from 0° to 15°, while the next 15° of temperature add 0 081 to the tension, the next 0 132, the next 0 219, and so on.

From this peculiarity a most important consequence flows If two saturated masses of air at different temperatures are combined, the resulting mass will be over saturated Suppose, for instance, that the masses are equal and that the temperatures are $t°$ and $(t+2t')°$ the tension of saturation at temperature $t°$ being e, and the tension at temperature $(t+t')°$ being $e+e'$ Then we know by what has just been shown that the tension at temperature $(t+2t')°$ will be greater than $e+2e'$ Say it is $e+2e'+2e''$ Then when the masses of air are mixed we have for the mixture a temperature of $t+t'$, while the tension of the total quantity of aqueous vapour which the double mass is called upon to retain is $\frac{1}{2}[e+(e+2e'+2e'')]$, that is $(e+e'+e'')$ But a temperature of $t+t'$, corresponds, by our supposition, to a tension of $(e+e')$ therefore the portion corresponding to the surplus tension e'' will be condensed

Under heads *Rain*, *Cloud*, &c, it will be seen that this principle has an important bearing on meteorological phenomena

SATURATION OF A MAGNET, POINT OF In magnetising steel bars with powerful magnets, or by means of an electric current, it is found possible to communicate to the bar an intensity greater than it is capable of permanently retaining, and this excess of magnetisation, as it may be called, is gradually lost till a certain limit is attained which depends entirely upon the molecular condition of the bar Thus for the same bar, the limiting point is higher or lower according as the bar is more or less hardly tempered, more or less hammered, twisted, and so on The bar when magnetised up to this point or to any point below it retains its intensity with great constancy This limit is called the *point of saturation* of the magnet, and the magnet when magnetised up to that point, is said to be *saturated* or *magnetised to saturation* It may easily be determined whether a newly magnetised bar is above its [illegible] tion by withdrawing from it its keeper once or twice and noticing whether it has lost [illegible] or If it be over magnetised; at each withdrawal it will lose intensity, and by repeated withdrawals it may quickly be reduced to the point of saturation To find whether it is below the point, it is only necessary to increase its magnetisation and observe as before whether it will retain more than it had (See also *Magnet*)

SATURN In astronomy the sixth planet in order of distance from the sun, the second of the family of major planets circling outside the zone of asteroids, and the planet which of all others presents the most remarkable and complicated structure Saturn's mean distance from the sun is 872,137,000 miles, his greatest 920,973,000, his least 823 301,000 Since the earth's mean distance is 91,430,000 miles, his distance from us varies from about 1,012,000,000 to about 732,000,000 miles The eccentricity of his orbit is considerable, being 0 055996 In fact the centre of his orbit lies midway between the earth's orbit and the sun His orbit is inclined 2° 29′ 28″ to the plane of the ecliptic In magnitude Saturn surpasses all the members of the solar system except Jupiter His equatorial diameter is about 70,150 miles, his polar about $\frac{2}{15}$ths less, so that his compression is very easily recognised with a good telescope In volume Saturn exceeds the earth no less than 696 7 times, but his density being only 0 13 (the earth's as 1), his mass only exceeds hers 89 7 times He is far inferior to Jupiter in mass, but even more markedly surpasses all other planets, since the combined mass of Uranus and Neptune, which come next to him in weight falls short of one third of his mass Like Jupiter he rotates very rapidly on his axis, the length of his day being about 10¼ of our hours His equator is inclined nearly 27 degrees to the plane of his orbit

Saturn is attended by eight satellites, and is besides adorned by a system of rings, so that his system far surpasses that of Jupiter in architectural richness His satellites differ very much amongst themselves in magnitude, the largest, Titan, being probably larger than any of Jupiter's satellites, while the smallest is probably less than a sixtieth part of our own moon in volume The observation of these satellites has not the same interest for astronomers as the study of Jupiter's satellites, because they are not seen readily enough to be of use in determining terrestrial longitudes, nor indeed would they be suitable for the purpose, as they are very seldom eclipsed or occulted by Saturn

The rings of Saturn are among the most remarkable objects which the heavens present to our study They were first recognised as rings by Huyghens in 1659, but Galileo had nearly fifty years before detected the remarkable changes of appearance presented by the Saturnian system as the orbital motion of Saturn causes the rings to be presented in varying directions towards the observer on our earth Galileo had first imagined that Saturn is triple, the ring as seen in his imperfect telescope seeming to show two large satellites, one on either side of Saturn. Finding some time afterwards that no trace of these imagined satellites remained, he was greatly perplexed. He afterwards watched the planet's changes of appearance, accumulating a sufficient number of observations to have removed his difficulty had he carefully studied their

significance Hevelius in like manner paid great attention to the varying aspect of Saturn without reasoning out its meaning After Huyghens' discovery of the real nature of the appendage, many observers examined Saturn with close scrutiny, and before long the brothers Ball detected a dark division going completely round the ring system, and apparently dividing the appendage into two distinct rings Cassini confirmed this discovery (indeed, to him is usually assigned the credit of having made it), and later Sir William Herschel very carefully re-examined the matter, and by showing that the dark marking can be seen on both sides of the ring-system, and apparently in an unchanged position, he proved that there really is a division He also detected signs of rotation, in the ring system though as Mr Webb has pointed out the evidence on which the rotation period assigned to the rings by Herschel actually rests, is sufficiently meagre and unsatisfactory In 1848 Bond and Dawes independently detected a dark ring within the bright rings This ring has at times been seen divided, and several divisions have from time to time been seen in the bright rings, though one only which divides the outer bright ring into two nearly equal rings seems permanent For the various theories which have been formed respecting the rings, see *Saturn's Rings*

The body of Saturn is marked like that of Jupiter by dark belts, somewhat fainter than Jupiter's, as might be expected from their greater distance, but disposed like his in a symmetrical manner with respect to Saturn's axis of rotation (See *Belts*)

A singular circumstance has been noticed by Sir William Herschel which deserves more attention than it has received The disc of Saturn does not always present an elliptical shape, but is sometimes seen with two greater diameters, intersecting and having their extremities in about 45 degrees of Saturnian latitude This appearance has been called Saturn's "square-shouldered" aspect Sir William Herschel was very confident that it was no illusion which [illegible] to the planet so abnormal a figure Nor was any peculiarity of his telescope [illegible] since he noticed the same appearance with two different telescopes Other observers also have noticed a similar appearance, amongst them the Bonds of America, Coolidge, Airy, and other practised astronomers On the other hand, careful measurements by Main and Bessel prove that the planet's normal figure at any rate is spheroidal It is difficult to consider observations made by such skilful astronomers as erroneous, nor is it easy to understand how any optical illusion can explain so strange an appearance Mr Webb has ascribed to the present writer a theory explaining the peculiarity as an optical one, but as a matter of fact that theory was only suggested to be immediately rejected So far as observation has yet gone there seems no escape from the conclusion that the globe of Saturn is subject to changes of shape of a most remarkable character, and indicating either the action of forces of upheaval or the formation and precipitation of cloud masses at an enormous elevation in the Saturnian atmosphere In either case an amount of energy is indicated which far surpasses the action which can fairly be ascribed to the sun's influence upon so distant a planet

SATURN'S RINGS An account of the discovery of these wonderful structures is given under the head *Saturn* The principal elements of the rings are as follows —

Longitude of ascending node of ring on the ecliptic,	167° 43′ 30″
Inclination of ring's plane to the ecliptic,	28 10 22
Annual precession of rising node of ring's plane on the ecliptic, or annual precession of the vernal equinox of Saturn's northern hemisphere,	3 145″
Complete revolution of either equinox in years,	412,080
Exterior diameter of the outer ring in miles,	166,920
Interior diameter of the outer ring in miles,	147,670
Exterior diameter of the inner ring in miles,	144,310
Interior diameter of the inner ring in miles,	109,100
Interior diameter of the dark ring,	91,780
Breadth of the outer bright ring,	9,625
Breadth of the division between the rings,	1,680
Breadth of the inner bright ring,	17,605
Breadth of the dark ring,	8,660
Breadth of the system of bright rings,	28,910
Breadth of the entire system of rings,	37,570
Space between the planet and the inner edge of dark ring,	10,322

Since the time of their discovery the rings of Saturn have been made the subject of much speculation Their unique character, the magnificent scale on which they are constructed, and their apparent stability in so strange a relation to the globe of Saturn, have suggested a variety of strange fancies respecting them. Maupertius, for instance, supposed that a comet passing near Saturn had been attracted by the planet and forced into the figure of a ring. Buffon sup-

posed that the equatorial parts of Saturn had once extended as far as the outer boundary of the ring, and that while the rest of the planet's material had contracted into the globe now actually presented by the planet, these old equatorial limits had been maintained unchanged where the ring is seen Another theory put forward by the younger Cassini has lately been successfully established by the united labours of Bond, Pierce, and Maxwell, as the true theory of the ring's constitution Cassini supposed that the rings consist of a multitude of minute satellites travelling in independent orbits around Saturn It need hardly be said that although this hypothesis has been shown to be well founded, we must assign the full credit of the discovery, not to Cassini, who put forward the hypothesis, but to the astronomers above named who have demonstrated it

The problem of determining how far a ring-system such as Saturn's could be supposed capable of remaining in equilibrium, assuming its component parts to be solid, about a globe like Saturn's, exercising mighty attractive influences on every part of the system, was discussed towards the close of the last century by the eminent French mathematician Laplace He succeeded in demonstrating that a uniform ring could not remain in equilibrium under such circumstances, but suggested the possibility that a ring weighted in some way along one part of its circumference might continue to rotate for an indefinite period, under conditions somewhat resembling those which affect the motions of an independent satellite In this state the problem remained until the discovery of the inner dark ring suggested the re examination of the conditions of stability with special reference to the case of a fluid ring Bond (one of the discoverers of the dark ring) and Pierce, both of America, dealt with this problem, the latter also considering the problem as dealt with by Laplace, and showing that for stability the ring system, if solid, must be divided into a very large number of concentric rings The subject of the stability of such a system as the Saturnian, regarded either as formed of continuous rings, solid or fluid, of rings of discrete bodies, or of a combination of discrete masses with fluid or vaporous portions, was proposed as the subject for the Adams prize in 1857 by the University of Cambridge The prize was awarded to Professor Maxwell, who contributed a masterly essay in which the question may be considered to have been finally disposed of He showed that even though a narrow ring, weighted along one part of its circumference, were so placed in rotation around Saturn as to continue for a time undestroyed, yet that, before long, disturbances such as we know affect the rings of Saturn, must inevitably cause the destruction of the ring. Still more, therefore, must we regard the existence of a complicated family of such rings as absolutely impossible, let the figure assigned to the several rings be what it may Professor Maxwell further showed that continuous fluid rings would be broken up into fluid satellites under the influence of the perturbations to which they would be subjected Dealing finally with the case of a ring of discrete bodies or minute satellites, Professor Maxwell showed conclusively that though such rings would be subject to changes of figure and disposition, yet these changes would not affect the permanence of the rings, that under certain conditions, far from improbable, such changes would proceed very slowly indeed, and finally, that such changes as might be expected to take place would not be different from those which, according to the best observations, seem actually to be taking place within the ring-system

Thus has the perplexing problem presented by the Saturnian ring-system been finally disposed of, in the opinion at least of all who are competent to weigh the significance of the mathematical processes involved in the research But what the actual constitution of this system may be, what the orders of satellites forming it, whether they are mixed up amongst (or surrounded by) vaporous masses, or are some of them in part or wholly fluid or vaporous, remains as yet undetermined

SCALES, THERMOMETRIC. See *Thermometer*

SCHEDIR. (Arabic) The star α of the constellation Cassiopeia.

SCHEHALLIEN EXPERIMENT See *Earth*

SCHWEINFURT GREEN See *Acetates*, *Aceto-arsenite of Copper*

SCINTILLATION (*Scintilla*, a spark) The act of emitting sparks or sparkling, applied to the twinkling appearance of the fixed stars Mr A Claudet (*Phil Mag*, No 175) has thrown some light upon this subject by an instrument which he calls the *chromatoscope* He attributes the beautiful sparkling, and changing colours, exhibited by certain stars on a clear night, to the evolution in different degrees of swiftness of the various coloured rays they emit. These rays are supposed to divide during their long and rapid course through space, and we see them following each other in quick succession, but so rapidly, that although we see distinctly the various colours, we cannot judge of the separate lengths of their duration Mr Claudet's instrument consists of a reflecting telescope, part of which is caused to rotate eccentrically in such a manner that, instead of a point, a *ring-like* image of the star is seen The rapidity of rotation is adjusted so that each separate colour given by the star is drawn out into a large

segment of the ring, and in that manner the light from the star can be analysed, as in a spectroscope

SCLEROTIC COAT. (σκληρος, hard) The outer coating of the eye, the white of the eye (See *Eye*)

SCREW A variety of the inclined plane It may be considered as an inclined plane wound round a cylinder, comparable to a winding inclined road round a steep hill, making a gradual ascent The projecting coils are termed the *threads* of the screw, and they may be either square or triangular The distance between the upper edge of one thread and the corresponding edge of the next, measured on a line parallel to the axis, is called *the distance between the threads* The screw is usually connected with a concave cylinder or *nut*, on the interior surface of which a spiral cavity is cut, corresponding exactly to the thread of the screw which moves in it When a weight is supported by a screw, the condition of equilibrium is found on the principle of the inclined plane (See *Inclined Plane*) Suppose a weight supported by a force applied at the circumference of a screw in a direction perpendicular to a plane through the axis If we suppose the surface of one thread of the screw cut horizontally and unrolled, we shall obtain an inclined plane in which a weight is supported by a force parallel to the base Consequently, the condition of equilibrium is, that the power shall be to the weight as the height of the plane to its base, or as the distance between the threads to the circumference of the cylinder

The screw is usually used with a lever inserted into the top of the screw Its length is reckoned from the axis of the cylinder, and its separate mechanical advantage is its length divided by the radius of the cylinder But it is easily proved that if we know the length of the lever it is not necessary to know the circumference of the cylinder, but that the power is to the weight supported as the distance between the thread is to the circumference of the circle described by the power Consequently, the mechanical effect of the screw is increased either by lengthening the arm of the lever or by diminishing the distance between the threads, but the latter cannot be performed beyond a certain limit without making the threads too weak to bear the strain upon them

The spiral curve formed on the cylinder, by supposing the threads to be reduced to a simple line, is called a *helix*

The form of the screw may be very varied The nut may be moveable and the screw fixed, or the screw moveable and the nut fixed, &c The screw is commonly used to exert pressure, as in the screw-press (See *Differential Screw*, *Endless Screw*)

SCREW, ARCHIMEDEAN. See *Archimedean Screw*

SCORPIO (The *Scorpion*) A sign of the zodiac The sun enters this sign on about October 23d, and leaves it on about November 22d The constellation Scorpio occupies the zodiacal region corresponding to the sign Sagittarius. This constellation is one of the richest in the heavens The brilliant red star Antares is its chief orb, but many conspicuous stars are spread over its extent Antares is a double star It had long been noticed that during the scintillations of this star a singularly well marked green tint became from time to time perceptible, and the idea was suggested that there might be a minute green companion to the ruddy Antares, but astronomers did not readily succeed in detecting it At length, however, Mitchell, using the fine refractor of the Cincinnatti Observatory, recognised a small green star near Antares Any doubt which might have existed as to the reality of the green colour of this companion was removed by an observation made by Mr Dawes during the occultation of Antares He found that when the primary was alone concealed the small star retained its colour The constellation contains many other objects of interest

SCORPIUS A name by which the constellation Scorpio is conveniently designated when there is occasion to refer to any stars belonging to it Thus Antares is called Alpha Scorpii, not Alpha Scorpionis.

SCULPTOR (Abbreviated from *Apparatus Sculptorius*, the Sculptor's Easel) One of Lacaille's southern constellations

SEA, INFLUENCE OF, ON CLIMATE See *Climate*

SEA SALT See *Sodium, Chloride*

SEASONS The name given to those four divisions of the year which correspond to the sun's apparent motion from the winter solstice to the vernal equinox (winter), thence to the summer solstice (spring), thence to the autumnal equinox (summer), and thence to the winter solstice again (autumn) As these motions of the sun are caused by a real motion of the earth, we have, in explaining the seasons, to consider the earth's position and motions We find the cause of the seasons in the relation between the earth's axial position and the position of her orbit-plane The axis is inclined to this plane at an angle of about 66½° (see *Obliquity of the Ecliptic*), and retains its position while the earth completes her circuit, so that if one could

look down upon the earth from a point at an indefinite height above the plane of the ecliptic, one would see the visible pole always bearing in the same direction, with respect to the centre of the earth It is clear then that as the earth travels round the sun, this pole so viewed would continually change its bearing with respect to the sun, at precisely the same rate as the earth's centre does When the pole so viewed seems to bear directly towards the sun, it is summer for the visible hemisphere. A quarter of a revolution further on, the pole would bear neither towards nor from the sun, then all the days and nights are equal, and it is autumn, a quarter of a revolution later the pole bears directly from the sun, and it is winter, and, lastly, yet a quarter of a revolution later the pole bears neither from nor towards the sun, and it is spring It need hardly be said that, where the pole has here been said to bear apparently directly towards the sun, the real inclination has been but $23\frac{1}{2}°$—the complement, that is, of the inclination of the earth's axis to the ecliptic

SECONDARY COIL See *Coil, Primary*

SECUNDA GIEDI (Latin and Arabic) The star α^2 of the constellation Capricornus.

SECONDARY AND PRIMARY RAINBOW See *Rainbow*

SELECTIVE ABSORPTION OF HEAT. See *Absorption of Heat.*

SELENITE. See *Sulphates, Calcium*

SELENIUM (Σελήνη, the moon) A non-metallic element much resembling sulphur, discovered by Berzelius in 1817 It forms a brittle, glassy mass of a deep brown colour, and a semi-metallic lustre Specific gravity 4 3 At the boiling point of water it softens, and melts at a little higher temperature It boils below a red heat, evolving a deep orange coloured vapour which condenses as a scarlet powder, or in black fused drops according to the temperature of the receiver Like sulphur, selenium forms several allotropic modifications Atomic weight 79 5 Symbol Se Selenium unites with oxygen in two proportions forming a *dioxide* (SeO_2) and a *trioxide* (SeO_3), the latter is only known in combination These are analogous to the corresponding oxides of sulphur, and are called *selenious* and *selenic acids*. They each form a well defined series of salts

SELENIURETTED HYDROGEN (SeH_2) A gaseous compound of selenium and hydrogen, possessing an intensely disgusting smell, and very poisonous When passed through metallic solutions it precipitates most of the heavy metals as *selenides* In its physical and chemical properties it is strictly analogous to the corresponding sulphur compound, sulphuretted hydrogen, or hydro sulphuric acid (which see)

SELENOGRAPHY (Σελήνη, the moon, and γράφω, to delineate) The art of picturing or describing the face of the moon We owe to Cassini, Schroter, Lohrmann, Beer and Muller, Schmidt, and others, the principal maps or drawings of the moon In Webb's Celestial Objects an excellent account and a very convenient map of the moon will be found Recently Mr Birt has paid great attention to lunar phenomena

SENSITIVE FLAMES This name is given to flames of gas which under certain conditions evince a wonderful susceptibility to the influence of sonorous vibrations They were discovered in 1865, in which year Barrett noticed that a shrill and prolonged note had a curious effect on a tall and slender gas flame that was burning from a tapering jet Under the influence of the sound the flame, which was about 14 inches long, shortened itself several inches, at the same time the upper part spread out sideways into a flat flame, which gave an increased amount of light from the more perfect combustion of the gas Less strongly the same effect took place when a high note was sounded even 40 or 50 feet away This singular phenomenon Barrett made the starting point of an investigation, in which he "succeeded in finding some of the conditions of its success, and so exalting the action that the flame moved at the slightest noise" In connection with this discovery it is to be noticed that mechanics have often had occasion to observe that the large bats-wing gas flames in their workshops became disturbed and thrust out little tongues of flame when the noise of the work happened to be sustained and shrill A similar observation to this had, it appears, been published some years ago in America by Leconte, who had remarked that during a concert certain of the gas flames in the room "exhibited pulsations in height, which were especially conspicuous when the strong notes of the violoncello came in" To Leconte is further due the happy and important observation that the flames did not jump until the pressure of the gas caused them to be near flaring Tyndall next took up the subject, and having largely added to its interest and importance, made the first publication of the discovery at a Friday evening lecture at the Royal Institution in January 1867

In order to obtain a sensitive flame attention is necessary to two things —The shape of the burner whence the gas issues, and the pressure urging the flow of gas. The former will be described directly, the latter should be as great as possible short of making the gas to flare. Any combustible gas will answer the purpose, but coal gas is the readiest and most suitable,

hence it is assumed as that employed If a piece of glass tubing be drawn out to a tapering orifice, about one-sixteenth of an inch in diameter, and the orifice snipped or filed into a slightly V shaped aperture, such a burner will yield a moderately sensitive flame when attached to the ordinary gas mains The best time to experiment is at dusk when the pressure of the gas is generally at its maximum The sound of a whistle or the higher notes of any musical instrument causes the flame to shrink down to half its height and spread out laterally like a fish tail flame, but immediately recovering itself the moment the sound has ceased Some amusing experiments dependent on this change in the luminosity and aspect of the flame at once suggest themselves When burning in a darkened room small print may be read at a distance from the flame, only when the flame is whistled to, or gun cotton may be placed near the flame and at the sound of the proper note the flame will diverge and ignite the cotton or fire a cannon Barrett has applied such a flame to the construction of an instrument which rings an electric bell at the least noise, and which may be turned to practical use in the detection of burglary, or revealing the approach of any shrill noise The instrument consists of two upright brass rods fixed to a little stand at a distance of some three inches apart Attached at right angles to the summit of one rod is a compound metallic ribbon, consisting of thin layers of silver, gold, and platinum welded together This arrangement, as is well known, expands unequally by heat, so doing it swerves aside and is thus brought into contact with a platinum terminal projecting from the top of the second brass rod Connected with the two rods is a cell of an electric battery, and associated with which is an electric bell The bell immediately rings when the electric circuit is complete, but under ordinary circumstances a gap of about half an inch is left between the metallic ribbon and the platinum terminal In front of the two upright rods and close to the metallic ribbon a sensitive flame is caused to burn By the divergence of this flame, under the influence of a high note, the metallic ribbon is heated, it swerves aside, and coming in contact with the platinum point closes the little gap in the electric circuit The ringing of the electric bell, may-be miles away, announces the fact almost simultaneously with the utterance of the sound which affected the flame

A still more sensitive flame may be obtained by urging coal gas from a gas-bag, or better a gas-holder, and allowing the gas merely to issue from a tapering jet The best jet for this purpose is made of steatite and similar to what is used for "jet photometers" By carefully increasing the pressure of the gas until the flame is just short of roaring, and allowing a perfectly free passage of the gas to the burner, a flame may be obtained fully twenty inches high if the surrounding air be perfectly still The least noise or the faintest sibilant, knocks the flame down more than a foot, the moment the sound ceases the flame promptly recovers itself The best sized orifice for the burner is one that just admits No 19 wire, or 0 046 inch in diameter, and the pressure of the gas required is about equal to 3½ inches of water The extraordinary sensitiveness of such a flame may be judged from the fact that it beats strongly in time to the ticking of a watch held near it, and that it responds to the chink of small coins shaken a hundred feet away

In a lecture, delivered before the Royal Dublin Society, Barrett has shown the value of such a flame as a delicate *phonoscope* Placing, for example, a watch in the focus of one parabolic mirror and a sensitive flame in the focus of another distant mirror, the reflection and convergence of sound is seen by the regular beating of the flame to every tick of the watch, an effect which immediately ceases when the flame is displaced from the focus by being brought nearer the watch Other laws of acoustics, such as the fact that a body—a bell, for example—when sounding is divided into ventral segments separated by intervals of rest, may be readily shown by a sensitive flame, also the refraction and interference of sound waves may be illustrated to a large audience by the same agency

This remarkable change in the aspect of a sensitive flame is wrought solely by the effect of sonorous vibrations, and is not at all due to the impact of puffs of air which may have attended the production of the sound The particles of air, if ever so violently displaced, could not struggle onward through the entangled barrier produced by their surrounding fellows, and could they possibly reach the flame their impact would be incompetent to produce an effect so strange and sure Hence this effect is solely caused by the wave-like to and fro motion by which sound is propagated from place to place It is the product of translated *motion*, not of translated *matter*

Now, the question arises, What is the cause of this phenomena? In the first place, it must be borne in mind that a sensitive flame is a flame on the point of roaring, and thereby on the brink of changing its aspect In the words of Professor Tyndall, "it stands on the edge of a precipice. The proper sound pushes it over It shortens when a whistle sounds, exactly as it did when the pressure was in excess The action reminds one of the story of the Swiss muleteers who are said to tie up their bells at certain places lest the tinkle should bring an avalanche

down The snow must be very delicately poised before this would occur I believe it never did occur, but our flame illustrates the principle We bring it to the verge of falling, and the sonorous pulses precipitate what was already imminent" A fuller explanation has been proposed by Barrett in the *Philosophical Magazine* for April 1867 A roaring flame is shown by means of a moving mirror to be a flame in a state of vibration, so also is a sensitive flame when influenced by a sound Now, suppose a gas flame to be very near its sensitive point, that is, if the gas ripples a little faster through the orifice the flame will change its shape and be thrown into a state of vibration Increasing the pressure of the gas an almost imperceptible amount will produce such an effect, and so also certain vibrations acting on the gas become equivalent to an increase of pressure in the holder Hence a sensitive flame is the analogue of a resonant column of air Both are caused insensibly to vibrate at any note, but when the pitch of the note accords with the normal rate of vibration of the flame or the air, then the flame visibly, and the column of air audibly, responds with energy to that note So that bringing the flame to the point at which it is sensitive to a particular note, is somewhat like adjusting the length of a column of air until it resounds to a certain tuning fork

Not only flames but streams of unignited gas or air, made visible by smoke, may be rendered extraordinarily sensitive Tyndall, enlarging the experiments of Savart, has further shown that jets of water under proper conditions are also capable of becoming exceedingly sensitive to notes of the proper pitch

For further information on this subject the reader is referred to the Sixth Lecture in Tyndall's work on Sound, and to a dissertation on Sensitive Flames, by Barrett, in the *Popular Science Review* for April 1867, to which article we acknowledge our indebtedness

SEPARATED TOUCH A technical term used in practical magnetism to designate a method of magnetisation According to this method, a pair of bar magnets are held inclined to the bar to be magnetised, and with their opposite poles resting on it They are placed on it in the middle, and they are then separated, one being drawn towards each end, where they are lifted and brought back without further contact to the middle, again separated, and so on The method of separated touch was invented by Dr Gowan Knight in 1745, and, owing to his great success in making powerful and even magnets, bears a high reputation See *Magnetisation*

SEPTUM (*Septum*, a fence) See *Dialysis*

SEREIN Rain which falls from a cloudless sky In tropical regions the phenomenon is not unusual

SERPENS (The serpent) One of Ptolemy's northern constellations It consists of two portions separated by the body of Ophiuchus

SEXTANS (Abbreviated from *Sextans Uraniæ*, the Sextant of Urania or Tycho Brahe's Sextant) A constellation invented by Hevelius, in honour of Tycho Brahé, and specially to commemorate the successful application of instrumental astronomy to the heavens by that astronomer The formation of this asterism can hardly be regarded as a useful service rendered to astronomy

SEXTANT (*Sextans*, the sixth part) An instrument having the figure of a sector of a circle, 60° in arc, used for measuring the angular distances between objects The frame bears a telescope directed to a small mirror, only half of which is silvered Thus one can look at an object through the telescope in the usual way, seeing through the mirror glass An arm moving radially round the sector bears another small mirror (placed over the centre of the sector), and, by moving the radial arm, this mirror can be so placed relatively to the other (both mirrors being at right angles to the plane of the sector), that rays from a star after reflection, firstly, at the face of the moveable mirror, and then at the face of the other, pass down the axis of the telescope Thus two objects can be seen at once, one directly through the telescope, the other after two reflections Now, it is obvious that, when a ray of light is reflected successively at the face of two mirrors, the last part of its course is inclined to the first part, at an angle which is twice the angle of inclination between the two mirrors (For if the second mirror were parallel to the first, the last part would be parallel to the first part, and shifting the second mirror would equally shift the perpendicular to the second mirror, with which the two last portions of the ray's course make always equal angles, so that a deviation equal to the angular movement of the perpendicular would result in each side of the perpendicular, or a double deviation on the whole) Hence we have only to double the angle between the two mirrors when both objects are seen in the same apparent direction, to determine the angular distance between the two objects The radial arm serves to show through what angle the mirror has been shifted, but each degree division is counted as two in numbering along the limb, so that by simple reading off one obtains the angular distance between the two objects directly The sextant was invented by Hadley, and is commonly called Hadley's sextant. For a full

account of the instrument, and a description of other forms in which it is used, see Loomis's excellent treatise on *Practical Astronomy*

SHADOW. (A S, *scadu*, *sceado*, Ger *schatten*, σκια, a shadow) As light moves in straight lines, it is intercepted by any opaque substance, producing the effect of a dark space, bounded by a more or less sharp outline, the shape of the intercepting body This is called the shadow When the light issues from a point, the sharpness of outline is very great, being interfered with by *diffraction* or *inflection* only When, however, the source of light has a sensible diameter (the sun, for instance), the shadow is bounded by a broad indistinct portion caused by the light not being suddenly cut off by the opaque body This portion is called the *penumbra*, the shadow being sometimes called the *umbra*

SHEAVE. (Old Dutch, *schyie*, orb, disc, wheel, German, *scheibe*). A wheel fixed in a block, and turning on a pivot It is grooved on its edge to receive cord, with which it rotates. This forms the common pulley (See *Pulley*)

SHELIAK (Arabic) The star β of the constellation Lyra

SHEL-LAC The name applied to the resin lac (see *Resins*) after it has been melted and strained from impurities

SHERATAN (Arabic) The star β of the constellation Aries.

SHOCK, LATERAL See *Lateral Shock*

SHOOTING STARS See *Meteors, Luminous*

SHORT-SIGHTEDNESS An imperfection of the eye caused by too great convexity of the *crystalline lens*, by which images of objects do not come to a distinct focus on the retina, but a little in front of it This may be perfectly remedied by correcting the excess of curvature of the *crystalline lens* by placing in front of the eye a slightly concave lens (See *Eye, Spectacles*)

SIDEREAL SYSTEM (*Sidus*, a star) The term under which astronomers include all the objects which fall within the limits of the system of stars whereof our sun is a member The most important problem in the whole range of the science of astronomy consists in the determination of the extent of the sidereal system, and the nature of the objects which must be supposed to belong to it

Undoubtedly, when Sir William Herschel began his wonderful series of labours amidst the stellar depths, there were just reasons for believing that the sidereal system is in fact no other than the stellar system, so that all objects which can be shown to be other than stars or suns must be regarded as lying beyond its limits For Sir William Herschel justly took the planetary system as affording the only available analogue of the sidereal system, and the planetary system, as known to that great astronomer, exhibited none of that variety of constitution which we recognise at the present time

Hence we find that the very basis of Sir William Herschel's system of star-gauging, the plan by which he hoped to define the limits of the sidereal system, consisted in the hypothesis that the stars are suns, comparable *inter se* in magnitude, and distributed with a certain general uniformity throughout space

But as his labours progressed, we find Sir William Herschel expressing doubts as to the justice of the hypothesis on which he was proceeding He found evidence in the star-groups he analysed that processes of aggregation and segregation had been at work, tending to destroy all uniformity of distribution, supposing such uniformity had ever existed within the sidereal system And, again, he recognised the existence, within the limits of that system, of objects altogether different in their constitution from the stars or suns His wonderful reasoning powers enabled him to pronounce confidently that many of the nebulæ are gaseous, or consist of some form of luminous mist, and not (as he judged to be the case with others) of stars resembling our sun He even went so far as to assert that the great nebula in Orion lies nearer to us than the stars seen in the same field of view In other respects also, he expressed doubts as to the justice of the hypothesis which had formed the basis of his earlier researches

Hence we may be permitted to look with considerable doubt on that theory of the sidereal system which has been regarded by many as exhibiting the positive teachings of Sir William Herschel (see *Galaxy*), and has been exhibited with more or less correctness in our treatises on popular astronomy.

It may be worth inquiring whether we ought not to commence by investigating the relations presented by the brighter stars, rather than pass at once beyond their limits, and consider the much more complicated questions suggested by the millions on millions of stars brought into view by the telescope

It is clear that, if the general principles which Sir William Herschel adopted as the basis of his researches are just, we might fairly expect to find among the stars visible to the naked eye a certain uniformity of distribution. The sphere within which such stars are included falls far

within the limits of the sidereal system, as figured under the form of a cloven disc by Sir William Herschel. On the other hand, it is extended enough and contains a sufficient number of stars to render us safe from mistaking arrangements really due to chance distribution for the signs of special laws of stellar aggregation.

Now, when we limit our attention to stars of the first six orders, we detect signs of special arrangement far too marked to admit of being disregarded. Instead of finding the lucid stars spread with a general uniformity over the heavens, we find them congregated more densely in certain regions than in others. In the northern hemisphere the lucid stars show a marked preference for the region covered by the constellations Cepheus, Cassiopeia, Lacerta, and Cygnus. In the southern heavens there is a corresponding but much larger region, even richer in stars than the northern one. It covers an area extending some forty or forty five degrees on all sides of the greater Magellanic Cloud. Within these regions and the part of the heavens covered by the Milky Way, lucid stars are distributed on the average three times as richly as over the rest of the heavens.

It is also worthy of notice that the southern hemisphere contains about 1000 more stars visible to the naked eye than the northern.

These relations lead one to regard the hypothesis of uniform distribution as untenable. If it be abandoned all the results which have been founded upon it must be abandoned also. In other words, the views which have been hitherto adopted respecting the sidereal system must be regarded as at the least unproved.

In viewing the sidereal system, independently of preconceived opinions, we are led to pay attentive consideration to many relations which might otherwise have been regarded as accidental. For example, while the stars were assumed to be comparable, *inter se*, in magnitude, and distributed with a general uniformity throughout space, it was unlikely that astronomers would look for any signs of association between the lucid stars and the Milky Way, or if any such sign attracted their attention for a moment, they would be disposed to reject at once the thought that it could be otherwise than accidental. Or again, if traces of the existence of star streams and star clusterings (of considerable extent) were recognised, they also would be dismissed, as resulting from mere coincidences.

But when once the whole subject is regarded as one that requires to be dealt with *de novo*, these and corresponding indications become all important. The means we have of solving the great problem are so few, "the material threads out of which a consistent theory of the universe is to be wrought are so slight" (to use the words of Sir John Herschel), that we cannot afford to lose even the slenderest clue which may serve by any possibility for our guidance.

This being the case, the attention of astronomers cannot be too urgently invited to the consideration of the various features of the heavens which may be regarded as likely to prove instructive. There are many branches of sidereal astronomy which have as yet been left almost wholly untouched. Researches into the numerical relations observed among stars of various orders, a careful consideration of the peculiarities of proper motion observable in different parts of the heavens, a comparison of the spectra of stars in one region with those of stars seen in others, a careful study of the relations observed among coloured or variable stars, these, and a multitude of similar subjects of inquiry, open a wide field of useful and profitable labour to the astronomer.

Amongst the results which have followed from inquiries of this sort, the following may be mentioned, rather as an encouragement to students of astronomy to pursue this particular line of research, than for the completeness of the evidence they afford respecting the sidereal system.

The nebulæ which, while the old theories respecting the sidereal system were unquestioned, came naturally to be regarded as external systems resembling it in character, are found to exhibit peculiarities of distribution, showing that they probably form part and parcel of the sidereal system. (See *Nebulæ*.) The red stars are found to affect the neighbourhood, and especially the borders of the Milky Way, and also to lie along the course of well marked star-streams. In the distribution of the variable stars, a similar peculiarity may be recognised. When the proper motions of the stars are mapped, it is found that in certain regions the stars are travelling collectively in one direction, or that among the stars covering a particular part of the heavens, two or three orders of proper motion only can be recognised. (See *Stars, Red, Stars, Variable, Proper Motions of the Stars*.)

Such relations as these, added to what has been already mentioned respecting the richer aggregation of lucid stars in certain parts of the heavens than in others, point to the conclusion that there is a variety of structure within the sidereal system, such as has not hitherto been adequately recognised. If we regard red stars or variable stars, as well as lucid stars generally, as associated in an intimate manner with the Milky Way, we have to regard that stream of

stars as, in a sense, *sui generis* Again, if we look on nebulæ as belonging to the sidereal system, we are compelled to recognise the existence of objects within that system wholly different from the fixed stars, whether single or multiple, and, lastly, if we accept the view that whole groups of lucid stars are travelling collectively through space, we are forced to recognise not merely the present existence of special laws of association, but the action of such laws on definite regions of space during long past ages

But the question further suggests itself whether, if we abandon the views formed by Sir William Herschel respecting the sidereal system, we must not with them abandon the view that our telescopes are powerful enough to reach the limits of that system What is the evidence we have that, in any direction, the limits of the sidereal system have been reached? It has been admitted that the appearance of irresolvable nebulosity in any part of the heavens is a proof that there, at any rate, the limits of the sidereal system lie beyond the range of the telescope which exhibits such nebulosity On the other hand, when the stars are seen separated from each other on a black background, it has hitherto been assumed without question that the limits of the system have been reached. Yet we have clear evidence, in the appearance of the Magellanic Clouds, that this criterion is deceptive For in Sir John Herschel's twenty-feet reflector the outer parts of the Magellanic Clouds were found to be quite irresolvable, whereas the central parts were clearly resolved Now it cannot for a moment be supposed that the difference in this case is due to a difference in the extent and distance of the star masses under examination It is perfectly obvious that here, at any rate, a difference of constitution is in question, that the stars forming the outer part of the Magellanic Cloud cannot be regarded as belonging to a stratum extending to far greater distances from the eye than those forming the central parts of the Nubecula It will be well to recognise the consequences which flow directly from this What is proved is, that so far as Sir John Herschel's twenty-feet reflector is concerned, irresolvable nebulosity in any direction does not necessarily signify enormous extension of the sidereal system in that direction But doubt is thus at once thrown on corresponding evidence in the case of any telescope, nor is there any reason for limiting the influence of the doubt to telescopic vision, it is obvious that what is true of the telescope is true of the naked eye Hence the existence of nebulous light in any part of the heavens, as seen by the naked eye, is no proof that the stars producing that light form a stratum of enormous extent in the direction of the line of sight Thus the farthest limits of the galaxy may be no farther from us than many stars separately visible

For the present it would seem well to regard the constitution of the sidereal system as an unsolved problem It must be remembered that Sir William Herschel himself expressed doubts as to the justice of the hypotheses on which he based his views We know, farther, that his ideas of the solar system, which suggested those hypotheses, were founded on inexact knowledge Astronomy has, in recent years, exhibited such a wonderful variety within the limits of the solar system, as to force on us the conclusion that if the solar system is to be regarded as supplying any evidence at all respecting the constitution of the sidereal system, that evidence points to infinite variety of constitution rather than to the uniformity imagined by Sir William Herschel So that we need not be surprised should it eventually appear that besides the primary suns, there exist, within the limits of the sidereal scheme, groups and systems of suns, whole galaxies of minor orbs, clustering stellar aggregations of every variety of form, richness, and distribution, all the various forms of nebulæ, circular, elliptical, and spiral, and widely extended gaseous masses clinging in fantastic convolutions around stars and star systems

SIDEREAL TIME See *Day*

SIDEREAL YEAR See *Year*

SIDE PRESSURE OF MOVING GASES If a mass of air move in any direction, in the midst of an atmosphere otherwise still, the latter will be set in motion and will strive to follow in the wake of the moving mass In effecting this it will undergo partial rarefaction This effect is exhibited on a large scale in nature when such rarefaction is detected by the fall of the barometer in the neighbourhood of the masses of moving air constituting storms On a smaller scale the same effect is shown in "Clement's Experiment" If a vertical tube be fastened to a hole in the centre of a circular disc, and another perfect disc of light material is brought near to the first one, when air is forced down the tube the second disc may be lifted The air passing vertically downwards through the tube strikes against the lower disc and tends, of course, to blow it away, but its vertical motion is converted into a horizontal one It passes from the centre towards the circumference of the parallel discs, and consequently has to expand to fill the larger space It becomes therefore dilated and diminished in tension, giving rise to a partial vacuum, the air beneath the lower disc presses up to restore the tension, and thereby forces up the disc The same may be shown by blowing air through a narrow tube a little on one side of a candle flame, which is a little beyond the end of the tube, the flame inclines towards

the current If a current of air be blown between two sheets of paper hung up vertically and parallel, the sheets will cleave together.

SIDERITE See *Quartz*

SIGNS OF THE ZODIAC See *Zodiac*.

SILEX. The old name for silica

SILICA. The chemical name of quartz, which see for its properties in the native state. Silica is an oxide of silicium, its formula being SiO_2. As prepared artificially in the anhydrous state it forms a white powder, insoluble in water, and in all acids except hydrofluoric acid It dissolves, however, in alkalies, especially on heating, it requires a very high temperature to fuse it, but melts before the oxyhydrogen blow-pipe to a transparent glass When heated with an alkaline carbonate it causes an evolution of carbonic acid, and melts to a perfectly transparent glass When prepared artificially silica unites with water and forms a gelatinous hydrate which is much more soluble than anhydrous silica, and by dialysing a solution of an alkaline silicate in excess of hydrochloric acid, Graham has obtained a clear solution of silica in water In this manner an aqueous solution may be obtained which, by concentration, contains as much as 14 per cent of silica, this solution is tasteless and colourless, and has a very faint acid reaction The addition of many substances, such as carbonic acid, an alkaline or earthy carbonate, &c, causes it to coagulate, when evaporated in a vacuum over oil of vitriol, a transparent glassy hydrate is left of the formula $SiO_2.H_2O$, other hydrates are supposed to exist, but their composition is uncertain, as the water appears to be held with very slight affinity Hydrate of silica is found native as opal and also as a white chalky deposit Silica possesses the property of an acid, and, owing to its being non volatile at a very high temperature, it displaces most of the other acids from their combinations, when united with bases these compounds are called *silicates* (which see), and their chemistry is in the highest degree intricate Many metallic silicates occur abundantly in the mineral kingdom, forming, in fact, the greater part of the earth's crust, they are mostly fusible, and are all insoluble in water with the exception of the alkaline silicates, they are all decomposed by hydrofluoric acid, but other mineral acids exert very various solvent powers upon them, they may all, however, be rendered soluble in dilute hydrochloric acid by fusion with an alkaline carbonate, carbonic acid being evolved, when heated with a fluoride, and strong sulphuric acid, the silica is all driven off in the form of gaseous fluoride of silicon

SILICATES —*Silicates of Aluminium* —Aluminium forms several silicates which are met with in nature The following are the most important, with their mineralogical names and formulæ, omitting the water *Collyrite* ($Al_2O_3.SiO_2$), *Staurolite* ($4Al_2O_3.3SiO_2$), *Andalusite, Kyanite*, and *Allophane* ($Al_2O_3.SiO_2$), *Porcelain Clay* from Guttenberg ($3Al_2O_3.3SiO_2$), *Kaolin* or *Porcelain Clay*, most varieties ($Al_2O_3.2SiO_2$), *Porcelain Clay* from Passau ($4Al_2O_3.9SiO_2$), *Cimolite* ($2Al_2O_3.9SiO_2$) There are a great many other silicates of alumina which are probably mixtures of various definite silicates The large family of clays may be included under this head, neglecting the iron, lime, &c, which they contain in variable proportions The double and multiple silicates containing more than one metal, and the mixtures of silicates with borates, aluminates, titanates, &c, are too numerous to be mentioned in detail

Silicate of Calcium —Several silicates of calcium are found native, the mono-silicate ($CaO.SiO_2$) is known under the name of *Wollastonite*, the sesquisilicate is known as *Gyrolite*, the disilicate is called *Okenite* Silicate of calcium can be obtained artificially by heating mixtures of pounded quartz and marble to bright redness Hydraulic mortar owes its property of hardening under water to silicate of calcium, and for this purpose, slaked lime is mixed with hydrated silica or minerals containing silica in such a state that combination will take place between the silica and the lime in the wet way Quartz or sand will not unite chemically with lime, and therefore ordinary mortar, which is a mixture of slaked lime and sand, owes none of its properties to the formation of silicate of lime, but hardens simply by drying, and by absorption of carbonic acid from the atmosphere

Silicate of Copper —Mono-silicate of copper is met with native, as *dioptase* ($CuSiO_3.H_2O$), and as *chrysocolla*, the former is of an emerald green colour, transparent, hard, and crystallised, the latter is massive, somewhat soft, semi opaque, and of a bluish green colour

Silicate of Iron —The mineral known as fayalite or *iron chrysolite* is of a black, greenish, or brownish colour, and of a specific gravity 4 1 Composition $2FeO.SiO_2$, this is also approximately the composition of some of the slags obtained in the manufacture of iron

Silicate of Lead —This silicate is only of interest in combination with borate of lead Faraday's heavy glass, by means of which he made his brilliant experiments on the action of magnetism on light, consists of a boro silicate of lead which he prepared by fusing oxide of lead, silica, and boracic acid together

Silicate of Potassium —A definite silicate can only be prepared by fusing together the atomic proportions of silica and carbonate of potassium, the *monosilicate* ($K_2O.SiO_2$) is then pro-

duced as a transparent glass, which is deliquescent in the air, and readily soluble in water, forming an alkaline liquid. By increasing the proportion of silica, compounds are produced which are not deliquescent, and are still soluble; thus, by heating 15 parts of silica with about 10 parts of pure carbonate of potash to bright redness for some hours, a *tetra-silicate* (K_2O $4SiO_2$) is produced, which is met with in commerce under the name of *water-glass*. This compound has the appearance of ordinary glass, and dissolves slowly but completely in boiling water; the solution is decomposed by all acids with separation of gelatinous silica; when exposed in thin layers to the air, it dries up to a tough glassy film, which is gradually decomposed by the carbonic acid in the atmosphere, leaving the silica behind as a compact insoluble coating. When the material on which the soluble glass is applied exerts a chemical action upon the silicate, (as when it contains carbonate of lime (chalk) or similar substances), decomposition takes place; the silica goes to the earthy base, and the mass gains very considerably in hardness. A piece of chalk treated in this manner becomes as hard as marble; on this account soluble glass (prepared either with silicate of potash, silicate of soda, or mixed silicate of the two) is largely used as a hardening material for building stones. When no substance is present in the stone capable of decomposing the alkaline silicate, a wash of chloride of calcium is subsequently given, whereby an insoluble calcium silicate is formed which fills up the pores, and confers hardness and power of resisting atmospheric influences. Alkaline silicates, together with silicates of calcium, lead, and other metals, form the several varieties of glass. (See *Glass*.)

Silicates of Sodium.—These silicates are so similar to the potash salts that the above description will hold good for them, allowance being made for the lower atomic weight of sodium.

Silicate of Zinc.—The hydrated silicate is found native under the name of silicious calamine or zinc glass.

SILICIC ACID. See *Silica.*

SILICIC ETHER. The researches of Ebelmen, and of Friedel and Crafts, have resulted in the formation of numerous compounds of silicic acid with organic radicals; amongst these we will only mention one or two of the most simple, and will confine ourselves to the ethers of ordinary alcohol. *Tetrethylic silicate* ($(C_2H_5)_4SiO_4$), a colourless liquid of ethereal odour and peppery taste, specific gravity 0.933, which boils at 165° C. (329° F.) It burns with a dazzling white flame, diffusing a thick smoke of silica; water gradually decomposes it, with separation of gelatinous silica.

Diethylic silicate ($(C_2H_5)_2SiO_3$) is a colourless liquid heavier than water, boiling at 350° C. (662° F.); it is decomposed by water. Moist air causes it gradually to solidify to a transparent mass, which in a month or two becomes hard enough to scratch glass.

SILICIURETTED HYDROGEN. The same as *Hydride of Silicon*, (*q.v.*)

SILICON, or SILICIUM. An element which forms the basis of silica. It is obtained in the free state with great difficulty. Atomic weight 28; Symbol Si. It exists in three different conditions—1. *Amorphous*, as a dull brown powder, insoluble in water; 2. *Graphitoidal*, obtained by heating amorphous silicon to a high temperature out of contact with air. Wohler has obtained it by another process in crystals; 3. *Crystalline*, or *adamantine*, in which state it has the form of long needle-shaped crystals, having a dark iron gray colour, and exhibiting iridescence like that of iron glance. At a temperature near the melting-point of cast-iron, silicon melts, and may be cast in a mould; the castings have a brilliant surface, and are not altered by exposure to the air. The principal compounds of silicon are as follows. *Fluoride of silicon* (SiF_4) is a gas which is formed by the action of hydro-fluoric acid on silica; it is colourless, and has a specific gravity of 3.6; it fumes strongly in the air, and is instantly decomposed by water into silica and silico-fluoric acid. *Silico fluoric acid* ($Si_2H_2F_6$) is the result of the action of water on fluoride of silicon. It is a very acid liquid, which fumes in the air and attacks metals, dissolving their oxides with formation of *silico fluorides*. The only silico-fluoride which need be mentioned is the potassium salt, which is remarkable for its great insolubility in water, one part requiring 833 parts of cold water to dissolve it. As the ammonium, lithium, and sodium salts are tolerably soluble, a solution of silico-fluoric acid is of considerable use in the laboratory as a test for potassium salts. *Hydride of silicon* is a colourless gas insoluble in water, and remarkable for being spontaneously inflammable; bubbles of it, on being allowed to rise through water, ignite at the surface with a brilliantly luminous flame, evolving a smoke of silica. Its composition is SiH_4. *Oxides of silicon.*—Silicon forms three oxides, only one of which is anhydrous; this is the di-oxide or *silica* SiO_2 (which see); the others are only known in combination with water; their names and formulæ are all that need be said about them: they are *Leucone* ($3SiO.2H_2O$) and *Chryseone* (Si_4O $2H_2O$).

SILICO-FLUORIC ACID. See *Silicon.*

SILICON, HYDRIDE OF. See *Silicon.*

SILVER. **A brilliantly white metal which was known to the ancients. Atomic weight**

108. Symbol Ag, from the Latin *Argentum* Specific gravity 10 5 It crystallises in cubes It melts at a heat estimated at about 1000° F When melted it absorbs oxygen, and just before solidifying it evolves it with effervescence causing spirting and projection of the metal. It is the best known conductor of electricity and heat, its specific heat is 0 057, it is extremely malleable and ductile, and has great tenacity, it is not oxidised at the ordinary temperature, and is unaffected by any atmospheric agent, except sulphur compounds which are sometimes present It is found either in the native state, or as sulphide or chloride It also occurs in small quantities in galena, gray copper ore, pyrites, and other minerals, and frequently in sufficient quantity to pay for extraction It is usually produced on the large scale by fusing its ore with a lead compound, and then cupelling (see *Cupellation*), or by amalgamation with mercury. It is also sometimes extracted in the wet way as chloride and sulphate The principal compounds of silver which require notice are the following —

Chloride of Silver occurs native as *horn silver* in waxy masses, possessing a specific gravity of 9 4 and of a pearl gray colour when freshly cut, turning brown on exposure to light Its composition is AgCl It is insoluble in water, and may be formed artificially by adding a soluble chloride to a solution of nitrate of silver In this condition it dissolves easily in ammonia, in hyposulphite of soda, and in cyanide of potassium, but is insoluble in most other solutions It melts at about 260° C (500° F) to a thin yellowish liquid solidifying to a horny mass It is reduced to the metallic state by zinc or iron in the presence of water Freshly precipitated chloride of silver is of a pure white colour, but it quickly acquires a dark grayish violet tint on exposure to light, more rapidly if free nitrate of silver is present This reaction forms the basis of several photographic processes (See *Photography*)

Iodide of Silver (AgI), is occasionally found native as *iodargyrite* in hexagonal crystals of a yellowish green colour It may be prepared artificially by adding a soluble iodide to a solution of nitrate of silver, it then falls down as an insoluble primrose-yellow precipitate, which, in the presence of nitrate of silver is coloured deep greenish gray on exposure to light Many reducing agents which have no action on iodide of silver before it is exposed to light will readily reduce it to the metallic state if it has been exposed for a very few seconds only to daylight Several photographic processes are based upon this reaction Iodide of silver is insoluble in water and dilute acids, and almost so in ammonia, it dissolves in concentrated solution of iodide of potassium, in hyposulphite of sodium and cyanide of potassium

Oxide of Silver The principal oxide is the *protoxide* (Ag_2O) which is a dark brown powder very slightly soluble in water, but sufficiently so to communicate to it an alkaline reaction, it is easily reduced to the metallic state by substances which absorb oxygen, many substances, such as creosote, taking fire when dropped upon it Oxide of silver is a powerful base, neutralising acids and forming with them well defined salts They are for the most part insoluble or sparingly soluble in water, although the nitrate, chlorate, perchlorate, fluoride, and some organic salts are soluble The most important salts of silver will be mentioned under the respective acids

SILVER ASSAY See *Cupellation*

SILVERED MIRRORS A method of depositing a brilliant coating of metallic silver on glass has been devised by Liebig The process is of great use in physical experiments, as the reflecting surface is on the outside of the glass, and the light does not, therefore, suffer modification in passing twice through the thickness of glass Moreover the glass, as it acts merely as a support for the silver surface, need only be worked true on the side which receives the silver, and veins and striæ in its substance do not interfere This plan of silvering glass is largely used in the manufacture of specula for reflecting telescopes, as discs of glass can be prepared and worked to a parabolic surface on one side at considerably less expense than would attend the production of mirrors of speculum metal Many modifications of Liebig's original process have been published, the most successful appears to be the one by which Mr Browning prepares his reflecting glass mirrors It is given in the *Chemical News*, vol xix p 12

SILVER, FULMINATING See *Fulminic Acid*

SINGING FLAMES When a small flame of hydrogen is caused to burn within a tube, a musical note is produced which continues so long as the flame remains ignited This fact was discovered by Dr Huggins in 1777 It formed the starting point of many subsequent investigations which have finally given rise to the so-called singing or musical flames De Luc, Chladni, Brugnatelli, Pictet, De La Rive, Faraday, Count Schaffgotsch, Rijke and Tyndall have all worked at and more or less enriched this subject Pictet and De La Rive believed the sounds to be due to pulses produced by the alternate expansion and contraction of the aqueous vapour produced by the combustion of the hydrogen Faraday showed that this explanation was incorrect by obtaining similar notes from the flame of carbonic oxide, which yields no water on combustion. he went farther and proved that any combustible gas, when burning within a tube, could be made to emit musical notes with more or less ease, for example, ordinary coal-gas

answers admirably Thus he abolished the restricted term "hydrogen harmonicon," by which these effects were hitherto known The cause of the sounds was attributed by Faraday to a rapid vibration of the flame produced by successive explosions of the burning gas He showed that feeble and rapid explosion always attended the combustion of gas Ordinarily unheard, or heard but slightly, these feeble noises rise to the dignity of a musical note when strengthened by the resonance of the tube placed over the flame Hence the length of the tube determines the pitch of the note given by the flame In fact, we may look upon a singing flame as similar to an organ pipe The noise of the burning gas has its analogue in the whistling of the air through the embouchure of the organ pipe And just as the vibrating column of air within the little singing tube reacts upon the jet of gas, causing it to vibrate in unison with itself (as may be proved by a moving mirror), so, no doubt, the air within the organ pipe urges the vibration at the embouchure to synchronise with itself, augmentation of sound being the result in both cases

SINGLE MICROSCOPE See *Microscope*

SINE COMPASS A not very appropriate name for the *sine galvanometer* (*q v*)

SINE GALVANOMETER An instrument used, but not very frequently, for measuring the strength of electric currents Its construction is much the same as that of the tangent galvanometer—namely, a small magnetic needle, turning in a horizontal plane, at the centre of a large vertical coil of pretty thick wire, but in the sine galvanometer, the coil of wire is made moveable round a vertical axis, which passes through the point of support of the needle To use the instrument, it is placed so that the needle, when pointing to zero on a scale beneath it, is in the magnetic meridian, and the plane which contains the coil also approximately in the plane of the magnetic meridian When the current passes, the needle tends to set at right angles to this plane, and takes a position depending upon the earth's directive force and the strength of the current The coil of wire is then turned round its vertical axis till its plane coincides with the magnetic axis of the needle When this is the case, the angle made by the needle with the plane of the magnetic meridian is read off, and it is easily proveable that the strength of the current is proportional to the sine of this angle

SINGLE TOUCH A technical term employed in practical magnetism to denote a method of magnetisation It is the very simplest possible method, and consists in stroking a bar to be magnetised always in the same direction with one pole of a powerful magnet, turning it over and stroking it again still in the same direction

SINUOSITIES The rate at which a tuning fork or other sonorous body is vibrating may be examined by means of combining the vibratory motion of the fork with a continuous motion in another direction, most advantageously at right angles to the direction of vibration A simple means of illustrating this method is to fasten a little pointed steel spring to one limb of a tuning fork, and, when it is in vibration, to draw over the point a smoked glass plate in a direction perpendicular to that of vibration A wave line or sinuosity will be thereby scratched on the glass The amplitude of the point's vibration will be the distance from hill to valley of the wave line, and if the motion of the glass be uniform, the number of hills and valleys in the sinuosity in a given length will vary with the rate of vibration—that is, the pitch of the note A given fork may, in this manner, be compared with a standard fork The two are set up side by side, and, being each provided with graphic points, and set in vibration, the blackened plate is drawn across both The rate of the plate's motion is now the same in both, so that the numbers of hills and valleys in the same length of the two sinuosities are in the same proportion as the pitches of the two notes In order to measure the absolute number of vibrations in a given time, the blackened surface must either be made to move across the point at a uniform and known rate, or marks must be made upon the surface at uniform intervals of time The "phonautograph" of Konig is a contrivance in which the latter method is adopted A cylindrical metal drum can be turned by a handle on its axis, which is a screw working into its support, so that when the handle is turned, the cylinder not only turns round but advances Hence when a fixed point is held against the cylinder, a spiral scratch will be formed, the development of which, on a plane, being a series of parallel straight lines This cylinder is covered closely with a sheet of glazed paper, which is then blackened over a smoky flame A fragment of feather is fastened to the end of the fork which is being tested, and the fork is fastened in a horizontal position, so that the feather just touches the cylinder Side by side with the fork is another feather, which is in such connection with a clock having a seconds' pendulum, that, at every second the feather is brought into momentary contact with the cylinder This is effected by making the pendulum of the clock at each oscillation complete a galvanic circuit, which creates an electro-magnet near the bent short arm of the lever upon which the second feather is placed The clock being set going, and the fork being made to vibrate, the handle of the cylinder is turned The feather on the fork gives rise to a sinuous line, while the feather in connection with the clock gives a series of dots side by side with the sinuosity. Since these

dots are made at intervals of a second of time, the number of sinuosities in the line between two dots gives the rate of vibration of the fork per second

SIPHON, or SYPHON In its simplest form is merely a tube open at both ends, and bent at an angle of about 45° C near its centre If such a tube be filled with water, its two ends closed and inverted, so that one end is in a basin of water, and so that the surface of water in the basin is at a higher level than the end of the tube outside, which may be called the longer limb, the water will rise in the shorter limb, pass the bend, and fall down the longer limb, so as to empty the basin, or, at all events, bring the surface of the water in it to the same level as that of the end of the longer limb The action of the syphon may be compared to that of a chain placed over a fixed pulley which turns with little friction, the chain being heaped at each end on a platform If the two platforms are of the same height from the ground, it is clear that the two portions on each side of the pulley will balance one another, but if one platform is lower than the other, the longer part will outweigh the shorter, and the chain passing round the pulley will heap itself on the lower stage In this illustration it is the tension of the chain which keeps it from breaking In the case of the syphon, we have a longer column of liquid outweighing a shorter one. The column is maintained entire or continuous by the equal pressure of the air on both open ends of the tube These pressures being equal and opposite, will not interfere with the motion The latter is brought about by a force equal to the weight of a column of water, whose height is equal to the difference between the vertical distance from the surface of water in the basin to the top of the syphon, and the distance from the open outer opening to the top of the syphon For it is clear, 1st, that the effort of the water in the shorter end, as far as the surface of the liquid in the basin, is neutralised by the pressure of the water in the basin, and, 2d, that the column of water in the shorter limb is counteracted by that in an equal length of the longer one By means of a syphon it is impossible to raise water more than 32 feet, because if a tube of such dimensions be filled with and inserted into water, then the top of the arch is more than that distance above the surface of the water, the atmosphere will no longer be able to support either column, and they will separate at the top Syphons which are used for decanting acids, spirits, &c, are usually provided with a cock near the end of the longer limb immediately above which is a tube opening into the longer limb, and being parallel therewith, this tube is open at the top The shorter limb being placed in the liquid, the cock is turned off, and the air is sucked out of the auxiliary tube The air then forces the liquid up past the bend and down the shorter limb At the moment it begins to enter the auxiliary tube the mouth is withdrawn therefrom, and the cock at the bottom of the longer limb is opened By this means no liquid is spilled, and there is no danger of any entering the mouth

SIPHON BAROMETER See *Barometer*

SIRIUS (Σείριος, *scorching*) The star α in the constellation Canis Major Sirius is the brightest star in the heavens It was described by Seneca as resembling Mars in redness, and by Ptolemy as similar in colour to Antares, a noted red star (*q v*) Aratus uses the term ποικίλος, which, however, according to the usage of the ancients, need not be intended to express colour The change of colour, if established by the evidence, is a phenomenon of the most remarkable character It may be, perhaps, associated with the change of position of this brilliant star Ruddiness is a common characteristic of stars near the Milky Way, and Sirius must have travelled several billions of miles from the neighbourhood of the Milky Way since the time of Seneca

SIROCCO The name of a hot wind blowing from the African desert across Sicily and South Italy, sometimes even extending so far as the Black and Caspian Seas Though coming from a rainless region, it is a moist wind when it reaches Italy, having acquired moisture from the Mediterranean It causes a feeling of intense weakness and depression

SKAT (Arabic) The star δ of the constellation Aquarii

SKY, POLARISATION OF See *Polarisation of the Sky*

SLEET Snow which has become half melted while in the act of falling

SLIDE VALVE A contrivance for alternately opening and closing the passages by means of which the steam can enter and leave the cylinder of a steam engine Various forms of slide valve are used, but they differ one from another but little in the principle of their action The *three ported slide valve* consists of a box with three apertures or *ports*, A, B, and C A communicates with the top of the cylinder, C with the bottom, and B with the condensing apparatus, or, in the case of high pressure engines, leads into the air The lid of this box is capable of sliding over it, and is hollowed on the inner side It is not large enough to cover all the three ports, but only two of them When the lid is over A and B, the steam from A can pass away from the cylinder through B, and at the same time C will be in communication with the boiler When the slide descends, the passage of the steam through C into the cylinder will be cut off, and that through A opened, and, at the same time, communication between C and B

will be established The steam will then enter by A above the piston, and pass out by C from below By lengthening the foot of the slide, the steam can be cut off from one part before it, is let into the other Another form of slide valve is termed, from its shape, the D valve

SMALT. A blue pigment prepared by melting together cobalt ores, potash, and silica so as to form a glass of the composition of double silicate of potassium and cobalt It is reduced to a minute state of division by levigation

SMEE'S GALVANIC BATTERY is made up of cells, each of which consists of a thin plate of silver, covered over with finely-divided platinum, and facing it on each side a plate of amalgamated zinc (that is, zinc coated with mercury by dipping in dilute acid and then rub the surface with mercury), insulated from the platinised silver, but connected together metallically A binding screw is attached to the platinised silver plate, and another to the zinc plates The *pair*, thus arranged, is placed in dilute sulphuric acid The terminal connected with the silver plate is positively electrified, that connected with the zinc negatively In this battery deposition of hydrogen on the plate not acted upon by the liquid, which, when permitted, gives rise to diminution of the current, is prevented mechanically The ruffled surface which is presented by the silver plate covered with very finely divided platinum has but little adhesion for the gas, which therefore rises to the surface as soon as it is generated

SNOW The frozen water which falls instead of rain when the temperature is below the freezing point The ultimate constituents of snow are tiny, six-pointed crystals of ice They assume in combination a thousand different figures, all exceedingly beautiful Scoresby, Glaisher, Lowe, and others have described and figured about that number of varieties, though doubtless there are many more (Professor Tyndall has shown, further, that the ultimate particles of ice are also these six pointed stars) The white colour of snow is caused by the commingling of rays of all the prismatic colours from the minute snow crystals Separately, the crystals exhibit different colours

Snow is usually from ten to twelve times as light as water, bulk for bulk , so that, where the snow falls pretty evenly, the corresponding rainfall is readily determined by merely measuring the depth of snow and taking one tenth of the result The more accurate plan, however, is to thrust the open end of a cylindrical vessel into the snow, inverting the cylinder, and then melting the snow in it

Snow plays an important part in the economy of nature In the first place, the mere transformation of the water particles into ice is a process during which a large amount of heat is given out , so that we may regard the formation of snow as a process tending to render the air currents warmer than they would otherwise be Then when the snow has fallen it serves to protect the ground, for, owing to its loose texture, it is a bad conductor of heat , so that, while checking the radiation of heat from the earth into space, it does not draw off the earth's heat by conduction The ground is thus often 20° or 30° warmer than the surface of the snow above it, and sometimes the difference of temperature has been more than 40°

Red snow and *green snow* have been met with, more commonly in Arctic regions, but also in other parts of the world These colours are caused by the presence of minute organisms—a species of alga called *Protococcus nivalis*

SNOW-LINE The line on mountain slopes below which all the snow which falls in the year melts during the summer Above the snow-line, therefore, lies the region of perpetual snow The altitude of the snow line depends on a variety of conditions The latitude of a mountain range is, of course, important in determining the position of the snow line, but many other circumstances have to be considered, as the shape and slope of the mountain, the aspect of either side of the range, the character of the surrounding country, the prevalent winds, and so on (See *Climate*)

The following table, showing the observed height of the snow-line in feet above the sea level in different places, is taken from Buchan's excellent " Handy Book of Meteorology "—

Place	Lat	Height	Place	Lat	Height
Spitzbergen,	78° N	0	North Himalaya,	29° N	19,560
Sulitelma, Sweden,	67° 5′	3,835	South Himalaya,	28	15,500
Kamtchatka, West America,	59 30	5,249	Abyssinian Mountains,	13	14,065
Unalaschta, .	56 30	3,510	Purace,	2 24′	15,381
Altai, . .	50	7,034	Nevades of Quito, .	0	15,820
Alps, . . .	46	8,685	Arequipa, Bolivia, .	16 S	17,717
Caucasus,	43	11,063	Paachata, Bolivia, .	18	20 079
Pyrenees, .	42 45	8,950	Portillo, Chili,	33	14,7[illegible]3
Rocky Mountains, .	43	12,467	Cordilleras, Chili, .	42 30	6,010
			Magellan Strait, .	53 30	3,707

(See further Humboldt's *Fragmens Asiatiques*, and the *Annales de Chimie*, tom xiv)

SOAP Combinations of the alkalies potash and soda with fatty acids, such as oleic, margaric, stearic acids, are what are usually called soaps, but the term is frequently extended to the fatty salts of other bases, thus oleate of lead, or lead plaster, is called lead soap, and the chemist speaks of copper soap, lime soap, zinc soap, &c Potash soaps are usually deliquescent and soft, and are known commercially as soft soap, whilst soda salts of fatty acids are hard, solid, and permanent in the air, and are known as hard soap Soap is perfectly soluble in hot water, but is insoluble in a dilute solution of common salt, and this reaction is frequently made use of in manufactures Ordinary hard soap consists of a mixture of oleate, palmitate, and stearate of soda When mixed with water it is decomposed into an acid salt, which precipitates as a turbidity (soap suds) and alkali, which dissolves It is partly to this alkali that the detergent action of common soap is due The blue, mottled appearance of some common soaps is due to the presence of iron or copper soap, which agglomerates in veins Marine soap is produced by the saponification of cocoa-nut oil This is soluble in dilute solution of salt, and is therefore applicable for use with sea water Yellow soap contains resin soap mixed with ordinary tallow soap Mr Gossage has successfully applied silicate of sodium as an adjunct to true soap As this possesses considerable detergent properties, it is a valuable addition, as it enables the price to be reduced without injuring the quality (See *Saponification*)

SODA See *Sodium*

SODAMMONIUM See *Sodium*

SODIUM A metallic element belonging to the alkali group, and bearing great resemblance to potassium, its compounds are very widely distributed in nature, the chloride being common salt In the metallic state sodium has a brilliant silver-white colour, it is of a waxy consistency at the ordinary temperature, at 95 6° C (204° F) it melts, and at a red heat volatilises Specific gravity, 0 98 Atomic weight, 23 Symbol, Na (from *Natrium*) When dropped upon water, it decomposes it with evolution of hydrogen, but the temperature generally does not rise to the point of ignition The following are the most important compounds of sodium —

Soda, hydrated oxide of sodium, or hydrate of sodium ($Na_2O\,H_2O$), known also as caustic soda, is a white opaque mass melting below redness, and solidifying to a fibrous cake, having a specific gravity of 2 0 It is deliquescent in the air, and rapidly absorbs carbonic acid, its solution is of a highly alkaline and caustic character, closely resembling a solution of potash It is now prepared in enormous quantities, and is used in many manufacturing operations

Chloride of Sodium (NaCl), known also as common salt, sea salt, rock salt, &c This very widely distributed substance is in the pure state a compound of the metal sodium with chlorine, it crystallises in colourless transparent cubes, which possess a specific gravity of 2 5 At a red heat chloride of sodium melts, and volatilises at a little higher temperature It dissolves in about three parts of water at any temperature, it is insoluble in alcohol, and in strong hydrochloric acid The other compounds of sodium which require notice are described under the headings of the acids Professor Seely (*Chemical News*, November 4, 1870) announces that anhydrous liquid ammonia dissolves metallic sodium, the liquid presenting all the physical characteristics of a true solution On evaporation the sodium is gradually restored to the metallic state, in the same continuous manner in which the solution has been effected The colour of the solution is a very intense blue, and its high tinctorial power is urged as an argument in favour of the idea that the metal is in simple solution Weyl (*Pogg Ann* cxxi 697) formerly prepared the same compound by condensing dry gaseous ammonia by pressure and cold on sodium, and considered it to be sodammonium NH_3Na Professor Seely, however, without adducing any arguments in support of his assertion, says that Weyl mistook the nature of this product

SOILS, CHEMISTRY OF The general principles of vegetable nutrition are explained elsewhere (See *Vegetable Nutrition*) A soil consists of a mixture of mineral substances resulting from the decay of rocks through atmospheric or other influences, and organic matter resulting from the decay of vegetable matter To these must be added those mineral and organic materials which are added in the form of manure That part of the surface which has been turned over by the plough or spade, and has become mixed with decayed vegetable matter, is called the soil proper, whilst the underneath portion, consisting chiefly of disintegrated rock, is called the *sub-soil* The mineral constituents of the vegetable are derived entirely from the soil, and the organic matter which it contains supplies carbonic acid and ammonia, these being also largely contributed by the atmosphere Soils vary greatly in their mineral constituents, and as the mineral ingredients of the plant also vary considerably, it frequently happens that a particular mineral substance, which the plant requires for its growth, is not present in the soil, this must

then either be supplied artificially in the form of manure, or some other plant more fitted to the available constituent of the soil must be cultivated thereon. It is not necessary that a substance should be soluble for it to be absorbed by the roots of a plant, although absorption is much easier when the salts are in solution. Salts, such as nitrate of ammonia, &c, brought down by rain, or scattered artificially over the surface, are not, as might be supposed, washed away by rain and lost in the drainage (except to some extent on very stiff clay or loose sand), but the soil has the power of absorbing the soluble constituents presented to it, and retaining them in a form readily assimilable by the roots. It may be taken for granted that good soils contain more than sufficient mineral ingredients for the proper development of any plant, but when a plant is grown on it year after year without artificial manure, the available amount of some constituent may become exhausted. If now the soil be allowed to lie fallow it becomes disintegrated by the action of heat, cold, and moisture, the rocks are acted upon by the carbonic acid brought down by the rain, and chemical changes take place which result in the liberation of a fresh supply of mineral nourishment. Hence the philosophy of sub soil ploughing, which brings unexhausted mineral matter to the surface, and of allowing the land to lie fallow periodically, by which means chemical disintegration of the rock mass is effected. But by a judicious system of rotation of crops the necessity of fallow may be avoided, as after a run upon one mineral ingredient a crop may be grown which requires excess of some other ingredient of which the first crop has not removed much, and so on, until, in the course of three or four years, a new supply of mineral matter will have been drawn from the almost unlimited stores of the soil, ready to be presented again to crop number one when it comes round in rotation.

SOLANO. The name of a south east wind blowing over Spain. It is hot and dusty, causing great uneasiness and a sense of irritation, insomuch that the Spaniard has a saying, "Ask no favour during the Solano."

SOLAR ECLIPSE. See *Eclipse*.

SOLAR MICROSCOPE. This is very similar in construction to the *magic lantern* and *megascope*, sunlight reflected from a *mirror* or *heliostat*, and concentrated by a converging lens being used as the illuminating agent. Owing to the large amount of light available when sunlight is used the lenses in the solar microscope are made of shorter focus than those in the *magic lantern* or *megascope*, so as to produce greater magnifying power.

SOLAR SPECTRUM. See *Fraunhofer's Lines*, *Spectrum*, *Spectrum Analysis*.

SOLAR SPECTRUM, NORMAL. See *Normal Solar Spectrum*.

SOLAR TELESCOPE. In observations on the solar disc it is desirable to employ an object glass of as large a diameter as possible. But the objection to this has always been that such an immense amount of heat is concentrated at the focus, that the dark glasses which should protect the observer are frequently shattered to pieces, to the great risk of the eyesight. A partial remedy for this evil is effected by diminishing the aperture of the object-glass, but the definition in this case is very inferior. Foucault has devised an ingenious method for close observation of the solar disc (*L'Institut*, 1866, pp 281, 313). Having noticed that no heat and very little light is transmitted through the thin bright coating on glass which has been silvered by Liebig's process (see *Silvered Mirror*), he coated the outer surface of the object-glass of a refracting telescope with such silvering, and found as he expected that all heat rays were reflected, as also the greater part of the light, so as to permit only a pale bluish violet to pass through. Leverrier has reported most favourably as to the results obtained by a nine-inch refractor (equatorial). No heat could be felt in the very focus of the object glass directed towards the sun, thus freeing all solar observations from a very great cause of error. Furthermore, only the ultra-red rays are really absorbed; all others are, as the prismatic spectrum shows, only diminished in intensity so as to give a steady and pure image of the sun, showing all details of outline and colour with excellent definition, and permitting the use of a magnifying power of 300. It is evident that an object glass so silvered is rendered useless for ordinary astronomical work. Instead, therefore, of silvering the object-glass, a sheet of plate glass with parallel sides is silvered, and this is placed in front of the object glass of the telescope when solar observations are desired. (See *Telescope*.)

SOLAR SYSTEM. The system of bodies of which the sun is the ruling centre. It includes the *Sun*, *Planets*, *Asteroids*, *Satellites*, *Comets*, *Meteors* (see *Meteors, Luminous*), and *Meteor Systems*. The different theories *Ptolemaic*, *Tychonic*, *Copernican*, *Keplerian*, and *Newtonian*, according to which the motions of the various members of the solar system have been regarded, will be found under their several heads. We propose here to consider briefly the general relations presented by the solar system.

From being looked upon as a system consisting of seven separate orbs, the solar system has come in our day to be regarded as a scheme whose constitution is of the most complex and diversified character. Besides the sun and the four minor planets which circulate nearest to

him we see the four major planets travelling along vast orbits, separated by distances far exceeding the diameter of the scheme of minor planets Between the schemes of the major and minor planets we see the zone of asteroids, whose members are doubtless to be counted in reality by thousands Then, dependent on the planets, we see the satellites,—one only of these secondary orbs being found within the scheme of minor planets, but around the major planets are systems of satellites forming miniatures of the solar scheme itself Around Saturn again circles that wonderful scheme of rings, including myriads of tiny satellites involved in a vaporous atmosphere Then we recognise families of comets attending on the sun, not, indeed, that very many such comets have been discovered, but because the laws of probability teach us that for each discovered sun-attending comet multitudes of others must remain undetected We recognise the existence of myriads of meteor-systems, and here, again, it is not that myriads have been actually discovered, but that the laws of probability *force* us to believe that for each meteor-system of the hundred passed through by the earth there must be thousands which she does not approach And finally, seeing that when the sun is totally eclipsed there blazes suddenly into view a glorious crown of radiating light, and remembering that even when he is only hidden from view by the earth's globe the outskirts of this glory are seen in the zodiacal light, we are led to believe that in the sun's immediate neighbourhood these meteoric and cometic systems are densely crowded, even if there be not mixed up with them other forms of matter as yet not clearly discerned by us

Such is the solar system as presented to us by modern astronomy Each year the economy of this wondrous scheme becomes more clearly understood, and each discovery presents more strikingly before us the singular complexity of structure and the amazingly exuberant vitality of that scheme which is second only to the sidereal system itself among the orders of created objects presented to the contemplation of mankind

SOLENOID A helix of wire made use of in electrical experiments (See *Electro-Dynamics*) It is constructed by winding stout copper wire upon a convenient cylinder of wood or pasteboard, which is then withdrawn from the helix formed the ends of the wire are then turned in so as to pass along the axis of the helix to the middle, where they are brought out between two of the turns and can be attached to the terminals of a battery in any required way The different parts of the helix are insulated from each other either by using covered wire, or, which is preferable, by using stiff wire and bending it so that the parts may not be in contact

SOLIDIFICATION is the passage of bodies from the liquid to the solid state The process is the reverse of that known as fusion It is accompanied by evolution of heat and in general by change of volume Two principal laws govern the phenomenon

(1) *Each substance solidifies at a fixed temperature if the pressure upon it be always the same, that temperature is the temperature of fusion for the body*

(2) *From the commencement to the close of the process the temperature of the liquid remains at this fixed point*

The influence of pressure upon the temperature of solidification is referred to under a separate heading (*Freezing Point, Influence of Pressure on*) Professor James Thomson showed that when bodies which expand on solidifying, as ice does, are subjected to pressure, the freezing point is lowered, while the application of pressure raises the point of solidification of bodies which contract on assuming the solid condition Under certain circumstances it is possible to cause a departure from the first law If water be deprived of air by boiling, and be permitted to cool under a layer of oil so as to prevent its absorbing more air, it may, if kept perfectly still, be reduced to a temperature many degrees below its freezing point, on enclosing it also in fine capillary tubes M Despretz lowered its temperature to $-20°$ C before it solidified In the first case, however, on causing solidification to take place, which may be done by gently disturbing the water or by dropping in a small spicule of ice, a quantity of ice is suddenly formed sufficient by the heat that it gives out to raise the temperature of the whole liquid to the ordinary freezing point, and solidification then goes on steadily and gradually if the water be connected with some arrangement for removing heat from it

The term solidification is sometimes, though not generally, applied to cases in which bodies are precipitated or crystallise from solutions

The reader will find some further remarks on this and the kindred subjects under *Fusion, Liquefaction, Latent Heat, Regelation,* &c

SOLIDS, SPECTRA OF INCANDESCENT With perhaps one exception (that of the rare earth Erbia), incandescent solids give a spectrum which is continuous from one end to the other Such spectra are classed by Mr Huggins as of the first order (See *Spectra of the First Order, Spectrum, Spectrum Analysis*)

SOLSTICE (*Solstitium*) The points where the sun reaches his greatest distance from the celestial equator are called the solstices, the *summer solstice* being the point of the sun's path

farthest to the north of the equator, the *winter solstice* the point farthest to the south When the sun is at the former point it is midsummer, when he is at the latter it is midwinter

SOLUTION When a liquid adheres to a solid with sufficient force to overcome its cohesion the solid is said to undergo solution, or to be dissolved Thus water dissolves salt, spirits of wine, resin, mercury, silver or lead, and so on By diminishing cohesion in the solid, as by reducing it to powder, solution is facilitated in consequence of the larger extent of surface exposed to the action of the solvent Heat also, by diminishing cohesion, favours solution The first portions of solid added to the liquid may disappear quickly, but as fresh portions are added solution goes on more and more slowly until it ceases altogether In such case the forces of adhesion and cohesion balance each other, and the liquid is said to be *saturated* The best method of watching solution is to suspend the solid in a muslin bag, or in a perforated vessel at the top of a column of water, when dense saccharine looking streams will descend, at first rapidly, and then more and more slowly, until saturation is attained During the cooling of a boiling saturated solution these saccharine looking streams may be seen long before a solid crust forms on the surface

Various solids dissolve in the same liquid at very different rates Baric sulphate may be said to be insoluble, calcic sulphate requires 700 parts of water for solution, potassic sulphate 16, magnesic sulphate 1½ When water is saturated with one salt it will dissolve other salts without increase of bulk Some curious details on this subject are given in the *Chemical News*, July 29, 1870

It sometimes happens that the addition of a second solid will displace the first, already in solution This happens where the adhesion between the liquid and the solid is weak, thus Prussian blue is dissolved by distilled water acidulated with oxalic acid, but it is thrown down on the addition of a solution of common salt, or of sodic sulphate

It does not always happen that heat increases the solvent powers of a liquid Lime is more soluble in cold water than in hot, so that cold water saturated with lime becomes turbid if heated So also a compound of lime and sugar, soluble in cold water, is separated from solution if heated to boiling Certain salts also attain a maximum of solubility long before the liquid reaches the boiling point Sodic sulphate, for example, is most soluble at about 33° C (92° F) than at higher temperatures Sodic seleniate and ferrous sulphate are further examples of this curious point Graham long ago pointed out that heat diminishes the force of adhesion as well as that of cohesion, the latter being in general more rapidly diminished by heat than the former force Hence in these exceptional cases the adhesion of the water decreasing in a greater ratio than the cohesion of the salt may account for the peculiarity in question But, on the other hand, common salt has sensibly the same solubility at all temperatures, between 0° and 100° C, whereas most salts, such as potassic nitrate, increase considerably in solubility as the temperature rises to the boiling point It would be a curious and interesting inquiry, as Professor Sullivan suggests, to endeavour to determine the condition of salts in solution at temperatures very much above the boiling point of water Boracic acid, for example, is volatile in the vapour of water, hence, it does not follow that salts would be precipitated when water under the influence of a high temperature assumed the gaseous state, but the saline molecules might still remain attached to the gaseous molecules

Solutions differ from chemical compounds in retaining the properties both of the solvent and of the solvend, thus, camphorated spirit retains the properties both of camphor and of spirit, but the properties of the chemical compound water, for example, have nothing in common with the properties of its constituent gases Moreover, solution is accompanied by a lowering of temperature, but where a definite chemical compound is formed, as when water and lime are brought together, heat is evolved

We have no very intimate knowledge as to the condition of compound bodies in solution In the case of hydrated salts it is probable that the water of crystallisation quits the saline molecules, and that the salt exists in solution in the anhydrous form This is highly probable in the case of sodic sulphate, which crystallises with ten atoms of water, as Mr Tomlinson has shown in a paper contained in the *Phil Trans* for 1868, and also in more minute detail in the *Chemical News* for the 3d and 10th December 1869

But the law of solubility up to the temperature of boiling water is scarcely known except in the case of a very few salts The elaborate inquiries that have been made on solutions refer more chiefly to other parts of physics than to solubility, such as the influence of salts on the boiling point, or the diffusion, or the capillarity, or the latent solution heat, or the atomic volume of saline solutions There are many points connected with solution that require investigation, but the inquiry is tedious and difficult, in order to secure correct results capable of graphic co ordination. (See *Supersaturation*)

SOUBRESAUT. A term applied by the French to the inconvenient and even dangerous

phenomena of *bumping* or *jumping ebullition* (See *Ebullition*) The term is from the Spanish *sobre*, upon, and the French *saut*, a jump or leap, thus the French speak of "les soubresauts d'un cheval," "les soubresauts d'une voiture"

SOUND (*Sonus*, a sound) Strictly speaking sound is an effect upon the brain, conveyed by the auditory nerve It is generally considered to include the conditions of the air which through the intervention of the ear affect the brain As a science it may be defined as the theory of vibrations in ponderable matter (See *Amplitude of Vibration*, *Beats*, *Chladni's Figures*, *Colours of Tones*, *Gamut*, *Graphic Representation of Vibrations*, *Interference of Sound*, *Kaleidophone*, *Loudness of Sound*, *Nodes and Segments*, *Pitch*, *Propagation of Sound*, *Reflection of Sound*, *Refraction of Sound*, *Resonance*, *Syren*, *Velocity of Sound*, *Vibration (Transversal) of an Elastic Rod*, *Vibration of a Stretched String*, *Wave Length*)

SOUND FIGURES See *Chladni's Figures*

SOURCES OF HEAT See *Heat, Sources of*

SOURCES OF LIGHT. See *Light, Sources of*

SPARK, ELECTRIC One of the forms in which accumulated electricity discharges itself It consists of the rushing together of positive and negative electricity across a non conducting medium with violent commotion and displacement of the intervening particles The phenomena most commonly presented by the spark through air, when no special precautions are taken, are a bright light, great heat, a sharp crack or report, and, if many sparks are passed in succession, an odour of ozone When proper arrangements are made, the phenomena accompanying the spark are very varied They depend on the amount of electricity discharged, on the way in which it is accumulated, on the surfaces between which the discharge takes place, and on the medium through which it passes The sparks obtained from the conductor of an electric machine are, under certain circumstances, very beautiful They are best observed by means of a Winter's plate machine, to the conductor of which is attached the large wooden ring—the peculiarity of this form of machine (See *Electric Machine*) They should be caused to pass between a small knob (1 in in diameter) and a surface very much larger than this At a distance of an inch or so, and with the machine in good order, a torrent of thick bright sparks appears to flow with a loud crackling noise, and if they be received on the knuckles, a sharp sting at the spot, with contraction of the muscles of the wrist, and, in sensitive people, even of the arm The apparent thickness of the line of light is due to the optical phenomenon known as *irradiation* When the distance between the surfaces is increased, the frequency of the sparks and their brilliancy is diminished, but if they be examined in the dark, they present a most beautiful appearance Springing from a thick root at the surface of the positive conductor, the spark reaches out crookedly towards the other surface, having a general appearance of one crooked stem furnished with off shoots The colour of it is reddish violet or purple in air With a good machine, and the best possible insulation—for this is essential—true sparks may be obtained fourteen inches or even more in length, when the distance is increased too much, the discharge then assumes the form of the *brush* The spark obtained from a Leyden jar or battery is never of any great length, though from the quantity of electricity accumulated, its effects are very powerful By means of a good battery of Leyden jars, the power of the spark in passing through even solid matter, and in completely breaking down the line of particles in its way, is easily shown If the discharge be passed through several sheets of thick paper, the paper is rent about the place where it has passed, and presents the appearance of being blown out from the middle at *both* sides of the paper, and not that which is produced by pushing a solid through from one side to the other The spark may also be made to penetrate a thick plate of glass on causing it to pass between two points, one of which is brought down upon the glass, and has around it a drop of olive oil If the points be made to dip at no great distance from each other under the surface of water, the water is projected with great violence in all directions, and if this be done within a tightly closed flask, it will be broken to pieces by the commotion produced in the water The heating effects are shown by means of Kinnersley's thermometer, which consists of a large upright glass tube into which knobs project at the top and bottom through air-tight fittings, from the bottom of the tube projects horizontally a smaller glass tube, which then turns up vertically, and is open at the top The larger tube is partially filled with water, which, however, does not rise to the level of the space where the discharge takes place, and which stands at the same height in the smaller tube When the spark is passed, the heat expands the air inclosed in the upper part of the principal tube, depresses the level of the water in it, and drives it up in the smaller tube The instrument also shows the powerful repulsive force exerted at the passage of the spark, for, at the instant of discharge, the water is suddenly driven outwards to a much greater extent that that which is due to the heat generated, and immediately falls back again to a level which depends upon the temperature. The heat of the spark is also shown in the ignition of a mixture of oxygen and

hydrogen When the spark is passed through gunpowder, the passage of the electricity is so very rapid that the powder is not inflamed, but merely scattered about, but if the rate of discharge is diminished by introducing into some part of the circuit a wet string instead of having a complete metallic circuit, the powder is readily fired The chemical effects of the spark in the production of ozone and nitric acid during its passage through air are described under *Electro-Chemistry* The electric spark, and all the other forms of disruptive discharge, were carefully examined by Faraday (See his *Experimental Researches*, vol i, or the *Transactions of the Royal Society* See also Sir W Snow Harris on the same subject, *Phil Trans*, 1834)

SPARK, DURATION OF ELECTRIC Wheatstone has shown, by means of his chronoscope, that, under certain circumstances, the passage of the electric spark occupies a sensible time The method of experimenting is described under *Chronoscope* and *Electricity, Velocity of* On causing the spark from the machine, or from a Leyden jar discharged in the ordinary way, to pass in front of the revolving mirror, the image appeared a mere point the same, in fact, as if the mirror had been at rest, but when the discharge took place through half-a mile of copper wire it was not so The image was then lengthened out into a line of light, owing to the angular displacement which the mirror had taken during the time of passage, and the persistence of the image on the retina, and by knowing the velocity of rotation of the mirror, and measuring the apparent length of the line of light, he estimated that, under these circumstances, the spark lasted $\frac{1}{24000}$th of a second It will be seen from what we have said here, and from our article on the velocity of electricity, that the duration of the spark depends upon the circumstances under which the discharge takes place

SPARK, GALVANIC When the terminals of a galvanic battery are brought very near to each other, a spark is observable It is best seen just before they touch, when they are gradually brought nearer to each other, and when they are again separated, a second spark is perceived The spark, on separating, is much stronger than that on putting the wires in contact, owing to the fact that, on making contact, there is a current induced in the wire opposite to the principal current, while, on breaking contact, an induced current, conspiring with the current from the battery, is set up

The distance across which a spark under ordinary circumstances will pass is excessively small, not $\frac{1}{20}$th of an inch, according to Sir W Thomson, for 5000 cells of Daniell's battery Gassiot, with a water battery of 3500 cells, obtained a passage of electricity over an air space of $\frac{1}{50}$th of an inch, which continued uninterruptedly for many weeks

SPATHIC IRON ORE See *Iron Ores*

SPECIFIC GRAVITY Specific gravity is the number expressing the ratio between the weight of any volume of a substance and the weight of an equal volume of some standard substance In the case of solids and liquids the standard substance is water, in the case of gases and vapours, it is usually hydrogen, sometimes atmospheric air It is clear that, whatever ratio may exist between a given volume of a substance and the same volume of water, must also exist between *any* volume of the substance and the same volume of water Thus, if a cubic inch of mercury weighs thirteen times as much as a cubic inch of water, a cubic foot of mercury weighs thirteen times as much as a cubic foot of water Accordingly, specific gravity concerns substance or material, while absolute weight concerns individual masses of water Various methods are employed for finding the specific gravity of gases and vapours The specific gravity of most liquids and solids is easily found in several ways The specific gravity of liquids is most accurately determined as follows —A little flask, holding about an ounce, is provided with an accurately fitting stopper, through the centre of which is a capillary opening This flask is weighed when empty It is then filled with distilled water, and the stopper is inserted, so that the excess of liquid is forced through the capillary opening of the stopper The excess of water being removed from the outside, the flask full of water is weighed The difference between the second weighing and the first is, of course, the weight of water which the flask holds The flask is now thoroughly dried and filled with the liquid whose specific gravity has to be found, in the same manner as it was filled with water The difference between the third weighing and the first is, of course, the weight of the liquid which the flask holds It is clear that the volume of the water and liquid are exactly the same We have found, therefore, the weights of equal volumes of the liquid and of water Divide the first by the second, and the specific gravity is obtained The specific gravities of very small quantities of many liquids may frequently be determined with great precision by a method suggested and employed by the author of this article For liquids which are insoluble in and not acted on by water, and which are heavier than water, a single drop of the liquid is placed in water, and a saturated solution of chloride of calcium is added, until the drop is in a state of indifferent equilibrium The specific gravity of the solution of chloride of calcium is then ascertained in the manner above described, and is, of course identical with that of the liquid. For liquids soluble in water, a

mixture of ether and bisulphide of carbon may often be employed, to which one or other constituent is added, until the liquid is in equilibrium. By this means the specific gravity of a quantity of liquid not larger than a pea can be determined with perfect accuracy.

The specific gravity of liquids can also be measured with great rapidity and with sufficient accuracy for many purposes by making use of the principle of Archimedes. (See *Displacement by Liquids*.) Thus, if a cylindrical rod of wood floats vertically in water in such a manner that exactly half its length is immersed, we know that the weight of the column of wood is equal to the weight of a column half as long of water. If the stick be then floated in oil, it will be found to sink deeper, say two thirds of its length. It follows, the weight of the same volume of wood as before is equal to the weight of two thirds of the volume of oil. Accordingly, half a volume of water has the same weight as two thirds of the same volume of oil, or

$$\frac{1}{2} W = \frac{2}{3} O$$

Therefore the volume of water weighs $\frac{4}{3}$ as much as the same volume of oil, and, accordingly, the specific gravity of the oil is $\frac{3}{4}$ or 0.75.

The various forms of hydrometer, areometer, lactometer, &c., depend upon this principle. They usually consist of a copper or glass bulb carrying above a cylindrical graduated tube, and loaded below with shot or mercury, so that they float upright. Those which, like the hydrometer, are used for determining the specific gravity of liquids lighter than water, such as spirits of wine, rum, &c., have the zero point marked close above the bulb at the root of the stem. This is the point to which the instrument sinks when placed in pure water.

Placed in pure alcohol the instrument sinks deeper (nearly to the top of the stem), because more of the latter liquid must be displaced before the weight of the displaced liquid is equal to the weight of the hydrometer. Taking pure water on the one hand, and pure alcohol on the other, making mixtures of 99 vols. of alcohol to 1 of water, 98 of alcohol to 2 of water, and so on, and, finally, 2 vols. of alcohol to 98 of water, 1 vol. of alcohol to 99 of water, and placing the hydrometer in each of these in succession, it sinks in succession less and less deeply. The points to which it sinks are marked on the stem, so that, when placed in an alcoholic mixture of unknown strength, the percentage of alcohol can be determined by reading off the point on a level with the liquid surface. For liquids which are heavier than water, such as sulphuric acid, milk, &c., the zero is marked at the top of the stem, and the distance at which the hydrometer floats out of the water shows the percentage of the heavier constituent in the mixture.

The most accurate way of determining the comparative densities or specific gravities of liquids, which is specially applicable for the measurement of the diminution of density which liquids undergo on being heated, is to connect two vertical tubes by a capillary tube at the bottom, and to place the two liquids, whose specific gravities are to be compared, (say water and ether) one in each tube. Since, when there is equilibrium, the pressure on either side of any plane drawn through the connecting tube must be the same, it follows that a shorter column of the heavier liquid will keep in equilibrium a longer column of the lighter one, and that, consequently, the height at which the two liquids stand in the two vertical tubes, measured from the capillary connecting tube, are inversely as the relative densities or specific gravities of the liquids. The heights are measured by a "kathetometer" or telescope, sliding on a graduated upright rod. The specific gravities of liquids which mix can be compared by the same means, provided that the two are separated by a little plug of mercury in the capillary.

Various methods are used for measuring the specific gravities of solid substances, depending upon the nature of the substances—that is, whether they are soluble in water, heavier or lighter than water, in the form of a powder, &c.:—

1. Let the body be a solid substance, not soluble in and heavier than water. A loop of human hair (which has very nearly the same specific gravity as water) is hung from the bottom of one scale of a balance and counterpoised. A fragment of the solid under examination is hung from the hair and weighed. This gives the actual weight.* It is then hung in water so as to be entirely submerged, and again weighed. Since (see *Displacement*) it is now pushed up by a force equal to the weight of the water it displaces, the loss it undergoes in weight when in the water—that is, the first weight *minus* the second is the weight of the water displaced—that is, the weight of a volume of water equal to that of the immersed solid. Accordingly the weight of the body divided by the weight it loses in water is its specific gravity. Thus if—

A body weighs 740 grains in air,
and 652 grains in water,

* Very nearly, but not quite, because a body in air is pressed up with a force equal to the weight of air it displaces. To get the true weight, we should have to add to its observed weight the weight of an equal volume of air.

the weight of a volume of water equal in volume to the solid is $740 - 652$—that is, 88 grains Therefore its specific gravity is $\frac{740}{88}$ or 8 40

2 If the body be soluble in or attacked chemically by water, some liquid is selected in which the solid is unacted on Thus, if the substance be sugar we may employ oil, or turpentine, or ether, &c. Thus let—

A body weigh 163 grains in air,
and 104 grains in oil,

we deduce that the weight of oil, whose volume is equal to that of the substance, is 59 grains What will be the weight of the same volume of water? Suppose the specific gravity of the oil, determined by the method given above, be found to be 75, this shows that the weight of any volume of oil is to that of the same volume of water as 75 is to 1 Accordingly the weight of water, having a volume equal to the volume of the 57 grains of oil, is $\frac{57}{75}$ grains, or 78 6 grains Finally, therefore, the specific gravity of the substance, which is the weight of a volume of it divided by the weight of an equal volume of water, is $\frac{163}{78 6}$ or 2 06

3 If the substance be not acted on by water, but be in so fine a state of division as to prevent its being hung from the scale pan, its specific gravity may be taken by means of the specific gravity flask, above described, as follows —Weigh the flask empty Put some of the powder in and weigh again Deduct the first weight from the second, and we get the weight of powder taken Fill up the flask with water (the powder remaining in), and weigh again Deduct from this weight the weight of the flask and the powder together, and we get the weight of the water required to fill up the flask when the powder is in it Empty out the powder and water, fill up with water and weigh, deduct the weight of the flask, and we get the weight of the water which fills the flask Deduct from this weight the weight of the water which fills the flask when the powder is present, and we get the weight of the water displaced by the powder—that is, the weight of a volume of water equal to the volume of powder Divide the weight of the powder by this weight, and the specific gravity of the powder is obtained.

4 If the substance be a powder soluble in water, methods 2 and 3 are combined That is, a liquid is selected without action on the powder and the weight of a volume of liquid equal in volume to the powder is found as in 3 Then, from the specific gravity of the liquid the weight of an equal volume of water is found as in 2 Whence the specific gravity is immediately deduced In determining the specific gravity of powders according to 3 or 4, care must be taken to free them perfectly from air This is done by boiling them in the liquid with which they are in contact, or if this cannot be done, by placing them for some time in vacuo when under the liquid

5 If the substance be a solid lighter than water, such as a fat or wax, the following method is employed The substance is weighed in air, let it weigh 100 grains A piece of lead is fastened to it sufficiently heavy to sink it, say 10 grains The two together in air weigh, of course, 110 grains Let the two be weighed together in water and weigh 4 grains Then $110 - 4$ or 106 grains is the weight of the water they displace together The weight of water which the lead displaces is at once found from its specific gravity, which is 11 3 The weight of water displaced by the lead is $\frac{10}{11 3}$ or 88 Therefore the weight displaced by the substance is $106 - 88$ or 105 22 Consequently the specific gravity of the substance is $\frac{100}{105 22}$ or 0 91

SPECIFIC GRAVITY OF SOLIDS, LIQUIDS, GASES, AND VAPOURS

SPECIFIC GRAVITY OF SOLIDS AT 39 2° F (4° C) WATER AT 39 2° F = 1 000

Agate,	2 615	Calcium,	1 578
Alabaster,	2 700	Celestine,	3 950
Aluminium,	2 670	Charcoal from—	
Alum,	1 700	Beech,	0 518
Amber,	1 080	Birch,	0 364
Anthracite,	1 800	Oak,	1 570
Antimony,	6 710	Chromium,	6 810
Arsenicum,	5 959	Coal,	1 330
Basalt,	2 700	Cobalt,	8 950
Bismuth,	9 799	Coke,	1 865
Brass,	8 300	Copper,	8 950
Bronze,	8 800	Coral,	2 680
Cadmium,	8 604	Diamond,	3 500
Calamine,	3 400	Dolomite,	2 800

Emerald,	2 700	Opal,	2 250
Emery,	3 950	Osmium,	21 400
Felspar,	2 450	Palladium,	11 800
Flint,	2 600	Pearls,	2 750
Fluorspar,	3 200	Phosphorus,	1 830
Galena,	7 580	Platinum,	21 530
Garnet,	4 100	Porcelain (Chinese),	2 380
Glass (Flint),	3 330	Porphyry,	2 700
Glucinum,	2 100	Potassium,	0 865
Gneiss,	2 650	Pyrites (Iron),	5 000
Gold,	19 340	Quartz,	2 650
Granite,	2 700	Rhodium,	12 100
Graphite,	2 300	Rubidium,	1 520
Gun Metal,	8 460	Ruby (Oriental),	4 280
Gypsum,	2 330	Ruthenium,	11 400
Heavy Spar,	4 430	Sapphire,	3 990
Hornblende,	2 950	Selenium,	4 788
Hypersthene,	3 380	Serpentine,	2 470
Ice,	0 920	Silver,	10 530
Iceland Spar,	2 720	Sodium,	0 972
Indium,	7 362	Steatite,	2 800
Iodine,	4 950	Steel,	7 810
Iridium,	21 150	Strontium,	2 540
Iron—Cast,	7 210	Sulphur,	2 050
Malleable,	7 840	Tellurium,	6 650
Ivory,	1 920	Thallium,	11 810
Jasper,	2 800	Tin,	7 292
Lead,	11 360	Titanium,	5 300
Lime,	3 180	Topaz,	3 560
Lithium,	0 593	Tungsten,	17 600
Magnesium,	1 743	Uranium,	18 400
Malachite,	3 500	Wood—	
Manganese,	8 013	Ash,	0 845
Marble (Parian),	2 840	Beech,	0 852
Mispickel,	6 120	Elm,	0 800
Molybdenum,	8 620	Cork,	0 240
Nickel,	8 820	Zinc,	7 146
Obsidian,	2 300	Zircon,	4 300

SPECIFIC GRAVITY OF LIQUIDS WATER AT 39 2° F = 1 000

Acid, Acetic,	1 063	Essential Oil of Bitter Almonds,	1 049
„ Hydrochloric (Liquid),	1 270	„ Cinnamon,	1 030
„ „ (Solution),	1 210	„ Spiræa,	1 173
„ Nitric (at 15° C),	1 517	„ Turpentine,	0 864
„ Sulphuric,	1 848	Ether, Acetic,	0 890
„ Nordhausen,	1 860	„ Hydrochloric,	0 921
Alcohol, Absolute (at 0° C),	0 815	„ Nitric,	1 112
„ Amyl, „	0 827	„ Oxalic,	1 092
„ Butyl, „	0 803	„ Sulphuric,	1 120
„ Ethyl, „	0 815	Mercaptan (at 0° C),	0 835
„ Methyl, „	0 817	Mercury (at 0° C),	13 596
„ Propyl, „	0 817	Milk (Cow),	1 030
Aldehyde (Acetic) (at 0° C),	0 800	Naphtha (Rectified Coal),	0 860 to 0 900
Ammonia (Solution),	0 875	Oil Almond (at 15° C),	0 918
„ (Liquid),	0 730	„ Castor,	0 969
Beer,	1 023 to 1 034	„ Cod liver,	0 928
Benzol (C_6H_6),	0 850	„ Linseed (at 12° C),	0 939
Bisulphide of Carbon,	1 272	„ Olive,	0 918
Bromine (at 0° C),	3 187	Tar (Coal),	1 120 to 1 150
Chloride (Tri-), of Phosphorus (at 0° C),	1 616	Water, Distilled,	1 000
Chloride of Sulphur (S_2Cl_2),	1 680	„ Rain,	1 001
Creosote,	1 057	„ Sea,	1 026
Cyanogen (Liquid),	0 866	Wine,	0 990 to 1 038

SPECIFIC GRAVITY OF GASES AT 39·2° F. (4° C.), BAROMETER = 29·9 INCHES = 760 MILLIMETRES

	Air=1·000	H.=1·0		Air=1·000	H.=1·0
Air,	1·000	14·40	Hydrochloric Acid,	1·247	18·25
Ammonia,	0·589	8·50	Hydrogen,	0·069	1·00
Carbonic Acid,	1·529	22·80	Nitric Oxide,	1·039	15·00
„ Oxide,	0·967	14·00	Nitrous Oxide,	1·527	22·00
Carburetted Hydrogen—			Nitrogen,	0·971	14·00
Heavy,	0·978	14·00	Oxygen,	1·105	16·00
Light,	0·557	8·00	Phosgene,	3·680	49·50
Chlorine,	2·470	35·50	Phosphuretted Hydrogen,	1·185	17·00
Coal-Gas, about	0·500		Sulphuretted „	1·191	17·00
Cyanogen,	1·806	26·00	Sulphurous Acid,	2·247	32·00
Hydrofluoric Acid,	0·689	10·00			

SPECIFIC GRAVITY OF VAPOURS

	Air=1·000	H.=1·0		Air=1·000	H.=1·0
Alcohol, Ethyl,	1·613	23·00	Ether, Acetic,	3·067	44·00
„ Methyl,	1·120	16·00	„ Oxalic,	5·087	73·00
Arsenic,	10·600	150·00	Faraday's Chloride of Carbon,	8·157	118·50
Benzol,	2·770	39·00	Hydrocyanic Acid,	0·947	13·50
Bisulphide of Carbon,	2·644	38·00	Iodine,	8·716	127·00
Bromine,	5·540	80·00	Mercury,	6·976	100·00
Camphor (Common),	5·314	76·00	Phosphorus,	4·420	62·00
Dutch Liquid,	3·450	49·50	Steam,	0·622	9·00
Essence of Cumin,	5·240	71·00	Sulphur (above 1000° C.),	2·230	32·00
„ Turpentine,	4·760	68·00			

SPECIFIC HEAT. When heat is communicated to a substance it performs various functions; for a portion of the absorbed heat is consumed in expanding the substance against the external resistance of the atmosphere or other surrounding medium (*External Work of a Mass of Matter*); a second portion is consumed in expanding the substance, that is, increasing the distance between its molecules, against the internal resistance due to the attraction of the molecules (*Internal Work of a Mass of Matter*), while the remaining portion of the heat increases the temperature of the substance, or, as we commonly say, heats it. Thus some of the absorbed heat disappears as heat and becomes molecular potential energy (which see), while the rest remains as heat. When the substance which has been heated is allowed to cool to its original temperature the molecular potential energy induced by the addition of heat again becomes sensible heat. Now it is quite obvious that as the molecules which compose different kinds of matter vary greatly in weight and in the intensity of their attraction for each other, the quantity of heat requisite to raise equal weights of different substances through the same temperature will also vary greatly. To express this, Irvine, a pupil of Dr. Black of Edinburgh, proposed the term *capacity for heat*, which was replaced in 1784 by Gadolin, by the term *specific heat*, now in general use. *Calorific capacity* is a term occasionally used for the same purpose.

The specific heat of a substance may be defined as the quantity of heat necessary to raise a certain weight (say 1 lb.) through 1° of temperature (Centigrade or Fahrenheit, usually the former), in terms of the heat necessary to raise an equal weight of ice cold water 1° in temperature. Specific heat is therefore measured in *heat units*, and under this head we have mentioned the various units employed. The processes which are used for determining specific heats have been described under the heading *Calorimetry*.

It is evident, from the above remarks, that the actual temperature of a substance, as shown by a thermometer, does not truly indicate the amount of heat which it has absorbed in acquiring that temperature, because the amount expended in interior and exterior work is unknown. If we take a number of small metal spheres of the same size but of different metals, and after heating them in hot oil to precisely the same temperature (about 190° C.) place them simultaneously on a cake of bees-wax about half-an-inch thick, we shall observe that the effect they produce varies greatly. Supposing them to be respectively iron, tin, and bismuth, we shall find that the iron sphere possesses heat enough to melt its way through the wax, while the tin scarcely sinks half-way into the cake, and the bismuth makes but little impression. This arises from the fact that the specific heat of iron is high, while that of bismuth is low, and of tin intermediate; that is to say, in cooling through a given range of temperature, iron gives out more heat than tin, and tin than bismuth; and conversely, in being heated through a given range of

temperature, iron absorbs most heat, an equal weight of tin less heat, and an equal weight of bismuth still less heat than the tin.

The following table shows some of the results obtained by M. Regnault, by means of the method of cooling. (See *Calorimetry*.)

TABLE OF SPECIFIC HEATS ACCORDING TO M. REGNAULT.

Name of Substance	Specific Heat	Name of Substance	Specific Heat
Acetic acid,	0.6501	Mercury,	
Alcohol,	0.0402	Molybdenum,	
Aluminium,	0.2143	Nickel,	0.1086
Animal charcoal,	0.2[illegible]	„ carburetted,	0.1163
Antimony,	0.0508	Osmium,	0.0311
Arsenic,	0.0814	Palladium,	0.0[illegible]
Arsenious acid,	0.1[illegible]78	Petroleum,	0.4[illegible]4
Bismuth,	0.0308	Phosphorus,	0.1887
Boron,	0.2352	„ amorphous,	0.1700
Bromine,	0.1129	Platinum,	0.0[illegible]
Cadmium,	0.0567	Potassium,	0.1696
Carbon	0.2411	Rhodium,	
Cast iron,	0.1298	Selenium,	[illegible]
Charcoal,	0.2415	Silicium,	[illegible]1774
Cobalt,	0.1067	Silver	[illegible]0570
Coke,	0.[illegible]008	Sodium,	[illegible]
Copper	0.0951	Steel tempered,	
Diamond,	0.1468	Sulphur, native,	
Dutch tears,	0.10[illegible]3	„ melted nearly [illegible] months,	[illegible]03
Gold	0.0324	„ recently melted,	[illegible]
Graphite,	0.2018	Tellurium,	[illegible]474
Iodine,	0.0541	Thallium,	[illegible]
Iridium,	0.0[illegible]26	Tin,	[illegible]
Iron,	0.1138	Tungsten,	[illegible]334
Lead,	0.0314	Turpentine,	
Lithium,	0.9408	Uranium,	
Magnesium,	0.2499	Water,	
Magnesia,	0.24[illegible]	Zinc,	
Manganese,	0.1217	Zirconia,	

It will be noticed that water possesses a higher specific heat than that of any substance in the table; the important effect of this upon the climate of islands is discussed elsewhere (*Ocean Currents, Effects of, on Climate*). If we compare the specific heat of water with that of some of the metals we see at once the great difference between them. In the case of mercury, for instance, the table gives us 0.0333 as its specific heat, while that of water is 1.0080, hence the specific heat of water is (1.0080 ÷ 0.0333) 30.27 times greater than that of mercury. In other words, a given weight of water requires thirty times the amount of heat to raise its temperature through a certain number of degrees, that an equal weight of mercury requires to raise it through the same number of degrees; and the reverse of this of necessity takes place, a given weight of water in cooling through, say one degree, gives out thirty times as much heat as the same weight of mercury in cooling through one degree. If we mix a pound of mercury at 100° C. with a pound of water at 0° C., the temperature of the resulting mixture will be about 3°. The mercury has lost 97°, while the water has gained only 3°, hence obviously the pound of water requires more than 30 times as much heat as the pound of mercury to raise it through the same range of temperature. The table also shows very clearly why, in the experiment with the cake of wax, mentioned above, the iron sphere melted its way through the wax, while the tin and bismuth did not fall through.

The specific heat of solids varies at different temperatures, and it is greater at a high temperature than at a low one; thus the mean specific heat of iron between 0° and 100° C. is 0.1098, while between 0° and 300° C. it is 0.1218. In the case of platinum the increase is much smaller. M. Pouillet has found the mean specific heat of platinum between 0° and 100° C. to be 0.0335; between 0° and 500° C., it is 0.03518, and between 0° and 1000° C. it is 0.03728.

The density of substances has considerable influence on their specific heat; as a general rule the specific heat diminishes as the density increases, and *vice versa*. By reference to the above table it will be seen that in the case of the three conditions of carbon, the least dense (charcoal) has a specific heat of 0.2415; the specific heat of the more dense (graphite) is 0.2018; while that of the most dense (diamond) is 0.1468. Now, inasmuch as the specific heat of a substance increases as its density is diminished, and as an increase of tempera-

ture produces a diminution of density by expansion (because as the molecules are moved farther apart by the motion of heat, the same number of molecules occupy a greater space), it is probable that the increase of specific heat due to rise of temperature is to be traced to the diminution of density consequent upon expansion. The specific heat of a liquid is generally greater than that of the same substance in the solid form. M. Person has made numerous experiments on this subject (*Annales de Chimie et de Physique*, tome xxi., xxiv., xxvii.), and the following table embodies some of his results:—

Name of Substance	Fusing point	Specific Heat	
		In the liquid condition	In the solid condition
Water,	0.0° C.	1.0000	0.5040
Chloride of calcium,	28.5	0.5550	0.3450
Phosphorus,	44.2	0.2045	0.1788
Sulphur,	115.0	0.2340	0.2026
Tin,	232.7	0.0637	0.0562
Bismuth,	266.8	0.0363	0.0308
Nitrate of soda,	310.5	0.4130	0.2782
Cadmium,	320.7	0.0642	0.0567
Lead,	326.2	0.0402	0.0314
Nitrate of Potash,	339.0	0.3319	0.2388

The specific heat of liquids increases with the temperature of the liquid, and at a greater rate than in the case of solids; thus the mean specific heat of water between 0° and 40° C. is 1.0013; between 0° and 120° C. 1.0067; between 0° and 200° C. 1.0160, according to the determinations of M. Regnault.

We come now to the specific heat of gases, and it is at once obvious that the conditions are changed. For, while the heat added to solids and liquids expands them of necessity under a constant pressure, (since by no available means can the expansion of solids and liquids be restrained), in the cases of gases it is possible to confine them within a given volume during heating. They may thus be heated under a constant pressure, and permitted to expand like solids and liquids when similarly heated; or they may be confined within a certain volume, and thus heated under a constant volume, in which case the pressure upon the sides of the containing vessel will increase as the heat increases. When a gas expands under a constant pressure, it will obviously perform a large amount of exterior work, and by reference to the article on the *Mechanical Equivalent of Heat*, it will be seen that Mayer's determination of this equivalent is based on the relationship between the amount of heat necessary to raise the temperature of a gas under a constant pressure, to that required to raise the gas through the same number of degrees under a constant volume, the excess of heat in the one case being consumed in the performance of mechanical work. The specific heat of gases and vapours is consequently greater under a constant pressure; that is, when they are permitted to expand, and thus to perform exterior work, than under a constant volume. The following table shows the ratio of the specific heat of various gases under a constant pressure to their specific heat under a constant volume, according to the determinations of Dulong:—

Name of Gas	Under a constant volume	Under a constant pressure
Atmospheric air,	1.421	1.00
Oxygen,	1.415	1.00
Hydrogen,	1.407	1.00
Carbonic acid,	1.339	1.17
Carbonic oxide,	1.428	1.00
Nitrous oxide,	1.343	1.16
Olefiant gas,	1.240	1.53

Regnault has found that the specific heat of a *given weight* of a perfect gas, (that is, a gas which is far from its point of liquefaction), does not vary with the density or pressure of the gas, and it hence results that the specific heat of a *given volume* varies as its density. Equal volumes of perfect gases, and of some compound gases, formed without condensation, possess

equal specific heats, but in all cases relating to the specific heat of gases, those which are condensible do not follow the laws which apply to perfect or practically perfect gases The following are some of the results obtained by Regnault —

SPECIFIC HEATS OF GASES AND VAPOURS UNDER A CONSTANT PRESSURE

Name of Gas or Vapour	Specific Heats	
	Equal volumes	Equal weights
Air	0 2375	0 2375
Oxygen,	0 2405	0 2175
Nitrogen,	0 2368	0 2438
Hydrogen,	0 2359	3 4090
Chlorine,	0 2964	0 1210
Bromine, Vapour of,	0 3040	0 0555
Carbonic oxide,	0 2370	0 2450
Ammonia,	0 2996	0 5084
Marsh gas,	0 3277	0 5929
Sulphurous acid,	0 3414	0 1544
Water, Vapour of,	0 2989	0 4805
Ether, Vapour of	1 2296	0 4797
Chloroform, Vapour of,	0 6461	0 1567
Acetone, Vapour of,	0 8264	0 4125
Benzole, Vapour of,	1 0114	0 3754
Turpentine, Vapour of,	2 3776	0 5061

The common volume in the first column may be taken as that occupied by a pound weight of air, the common weight as one pound, and the unit as the specific heat of one pound of water, now it is obvious from the table that one pound of air existing under a constant pressure will require an amount of heat to raise it one degree in temperature equal to 0 2375 of that which the pound of water will require, or, in other words, the quantity of heat necessary to raise one pound of water one degree in temperature would raise about 4 2 lbs of air one degree If we take into account the relative densities of water and air, we find that a given volume of water requires the same amount of heat to raise it through a given temperature, as 3234 times its volume of air would require to raise it through the same temperature under a constant pressure

We have mentioned above that a substance generally possesses a higher specific heat in the liquid than in the solid form, now in the gaseous condition the specific heat is again lowered, and is less than it was in the liquid condition Thus the specific heat of water is double that of ice, and rather more than double that of steam, the specific heat of bromine is 0 0833 as a solid, 0 1060 as a liquid, and 0 0555 as a gas, again, the specific heat of ether is 0 5290, and of ether vapour 0 4797 (See also *Atomic Heat*, *Calorimetry*)

SPECIFIC INDUCTIVE CAPACITY See *Capacity, Specific Inductive*, and *Induction, Electro Static*

SPECIFIC REFRACTIVE ENERGY See *Refractive Energy, Specific*

SPECIFIC ROTATORY POWER A term used in connection with the *circular polarisation of bodies* It expresses the angle of rotation which a column of a substance of standard length and density imparts to a particular ray of polarised light

SPECIFIC THERMAL RESISTANCE See *Conduction of Heat*

SPECTACLES (*Spectaculum*, from *specio*, to look at) Lenses to fix in front of the eyes for the purpose of rendering vision more distinct Long-sighted eyes require convex lenses, whilst short-sighted eyes require concave lenses These are usually of equal curvatures on each side (See *Eye*, *Long-sightedness and Short-sightedness*, *Lenses*)

SPECTRA, BUNSEN'S METHOD OF MAPPING See *Mapping Spectra, Bunsen's Method of*

SPECTRA, DIFFRACTION. See *Diffraction Spectra.*

SPECTRA, METALLIC See *Coloured Flames*

SPECTRA OF COMETS See *Cometary Spectra*

SPECTRA OF METEORS See *Meteoric Spectra*

SPECTRA OF NEBULÆ See *Nebular Spectra*

SPECTRA OF THE FIRST ORDER This term is employed by Plucker to distinguish the spectra of gases at a comparatively low temperature from those given at higher tempera-

tures (See *Nitrogen, Spectrum of*) Mr Huggins used this term to express a continuous spectrum

SPECTRA OF THE SECOND ORDER Plucker designates by this a form of gaseous spectrum which is apparent when a high temperature is employed (See *Nitrogen, Spectrum of*) Mr Huggins uses this term for the spectrum of bright lines given by an incandescent gas

SPECTRA OF THE THIRD ORDER A term employed by Mr Huggins to distinguish a spectrum in which *dark lines* are visible

SPECTROSCOPE (*Spectrum*, σκοπεω, to view) An instrument for forming and examining the spectrum It consists of two telescopes, ordinarily of from ten to twenty inches focus, arranged on a stand with the two object glasses facing each other The eye-piece of one is removed, and in its place is a narrow slit formed of two straight edges of metal, adjustable with screws so as to allow a line of light of any desired width to enter the instrument If the two telescopes are now placed in a line, the slit being illuminated, an observer at the eye-piece of the other telescope will see a magnified image of this slit in the form of a brilliant line of light Now, let a glass prism be placed in the instrument between the two telescopes and let the observing telescope be turned round so as to bring it into the path of the ray of light which has been deflected by the prism, and suppose the slit is illuminated with homogeneous light—that from a soda flame, for instance—the observer will still see in the telescope an image of the slit as sharply defined as before, since the prism has only *deflected* the ray from its course, but can exert no dispersive action on it because the light is homogeneous Now, while everything remains as before, let a flame coloured with thallium, as well as sodium, be placed in front of the slit, in this case we have two rays of light passing through the prism, one homogeneous yellow, as before, forming a yellow image of the slit, and another homogeneous green from the thallium, forming a green image But these two colours have different refrangibilities two images of the slit will therefore be seen side by side, one bright yellow and the other bright green, the latter being more refracted from the original direction of the light than the yellow image Let us now introduce a third substance into the flame, viz, lithium This will emit homogeneous red light, and consequently in the observing telescope a red image of the slit will be seen by the side of the other two, and not so much refracted as either of them If, therefore, the observer places at one end of the instrument a spirit lamp, in the flame of which are compounds of the the three metals, lithium, sodium, and thallium, and looks through the eye-piece at the other end, he will see three coloured images of the slit, or, in other words, three coloured lines—red, yellow, green—separated by a definite interval This appearance is called the spectrum of the light, and the instrument is called a spectroscope In this description the principle rather than the details of construction have been given, these vary with almost every maker The prisms are increased in number from two or three up to fifteen or twenty, they are either of the ordinary triangular shape, or are so constructed as to give dispersion without refraction (See *Prism, Direct Vision*) The slit is furnished with delicate screw adjustments, and frequently also with a reflecting prism, so as to get two spectra in the field of view at the same time, whilst the observing telescope is caused to move along the graduated arc of a circle furnished with verniers, and a micrometer is frequently attached to the eye-piece The whole is enclosed so as to prevent extraneous light from interfering with the delicacy of the observations The object glass of the telescope to which the slit is attached is called the *collimating lens* At the Liverpool meeting of the British Association, held in September 1870, Mr J Browning brought forward an improved instrument which he calls an Automatic Spectroscope It is provided with a battery of six equilateral prisms, their bases being linked together by their corners, and the whole chain being then bent round so as to form a circle with the apices outwards To the centre of each base is a projecting radial rod having a slot in it which passes over a fixed centre pin common to all The first prism of the train is a fixture, and the other prisms are all enabled to move in proportion to their distance from the first Thus, if the second prism moves through an arc of 1°, the third will move 2°, the fourth 3°, the fifth 4°, whilst the sixth will move through an arc of 5° All these movements take place simultaneously upon moving the observing telescope, and the amount of motion of each prism and of the telescope is so arranged that the prisms are automatically adjusted to the minimum angle of deviation for the ray under examination On removing the eye-piece from the observing telescope and looking in at the object glass, the whole field is found to be filled with the light of the colour of that portion of the spectrum which the observer wishes to examine, whilst in a spectroscope of the usual construction, at the extreme ends of the spectrum just where the light is most required only a lens-shaped line of light would be found in the field of view Owing to this, more of the red and violet ends of the spectrum can be seen than in an ordinary spectroscope, and the H lines, which are generally so difficult to see, come out in a very distinct manner (See *Spectrum*)

SPECTROSCOPE, STELLAR See *Stellar Spectroscope*

SPECTRUM (*Spectrum*, an image) When a ray of white light falls upon a prism it is refracted, and at the same time dispersed, its component colours being spread out, forming the spectrum of the light By passing the light, in the first place, through a very narrow slit (from the $\frac{1}{100}$th to the $\frac{1}{1000}$th of an inch wide), and then letting it pass through several prisms and lenses (see *Spectroscope*), the spectrum may be obtained of a high degree of purity—that is, the different coloured images of the slit are arranged side by side in the order of their refrangibility without overlapping each other, even in some cases showing blank spaces between them Sir Isaac Newton, who first observed the prismatic decomposition of light, considered the spectrum to be divided into seven colours—red, orange, yellow, green, blue, indigo, and violet, but no sharp line of distinction can be observed between any of these colours, as they shade into one another through infinite gradations When great accuracy is required in speaking of any particular part of the spectrum, it should be referred to one of the well defined lines in the solar spectrum, to one of the bright lines or absorption bands of artificial spectra, to the number on Kirchhoff's scale (see Roscoe's *Spectrum Analysis*, page 180, &c), or to some numerical standard, taking the distance between two well defined lines as 100, or the actual wave length of the light may be given (See *Absorption Lines of Spectrum*, *Absorption*, *Spectra*, *Atmospheric Lines of the Spectrum* *Aurora Borealis*, *Spectrum of*, *Bessemer Flame*, *Spectrum of*, *Blood Absorption*, *Lines in*, *Brewster's Theory of the Spectrum*, *Cæsium*, *Spectrum of*, *Carbon*, *Spectrum of*, *Chlorine*, *Spectrum of*, *Coloured Flames*, *Corona*, *Spectrum of the*, *Electric Brush and Glow*, *Spectrum of*, *Electric Light and Spark Spectrum of*, *Elements*, *Spectra of the*, *Fraunhofer's Lines*, *Geissler's Tubes*, *Kirchhoff's Theory of the Lines in the Solar Spectrum*, *Lithium*, *Spectrum of*, *Lightning*, *Spectrum of* *Mapping Spectra*, *Nitrogen*, *Spectrum of*, *Normal Solar Spectrum*, *Oxygen*, *Spectrum of*, *Phosphorus*, *Spectrum of*, *Spectrum Analysis*, *Spectrum*, *Illuminating Power of the*, *Spectrum Microscope*, *Spectroscope*, *Stars*, *Spectra of*)

SPECTRUM ANALYSIS A term applied to a method of qualitative analysis which has been recently introduced, and by means of which important discoveries, bearing on the distribution of the chemical elements not only in new terrestrial localities, but also in the sun, fixed stars, comets, and nebulæ, have been obtained By its means four new elements have been discovered, viz , cæsium, rubidium, thallium, and indium We have explained elsewhere (see *Fraunhofer's Lines*, *Spectrum*) that when a very pure solar spectrum is obtained it is traversed by an immense number of sharp black lines To simplify the explanation, we will take one as an illustration The double line known as Fraunhofer's D in the yellow, one of the most conspicuous has long been known to occupy exactly the same place as a luminous double line produced by sodium compounds when introduced into the flame of a spirit lamp , in fact, by placing such a spirit flame before the slit of a spectroscope the luminous lines could be made to fill up and absolutely obliterate the black D lines The relationship which was suspected to exist between the luminous and the black lines was first clearly proved by Kirchhoff in the autumn of 1859, who, as the result of his experiments, was led to the discovery that the incandescent vapour of sodium, which has a very high power of emitting the yellow light D, possessed in an equal degree the power of absorbing that same light In general terms, the law may be considered an extension of Dr Balfour Stewart's law of exchanges, and may be expressed as follows — Every substance which, at a given temperature, emits light of a certain refrangibility possesses, *at the same temperature*, the power of absorbing light of that refrangibility What was proved to be true in the case of sodium has since been shown to hold good with every other element , and the black lines in the solar spectrum are now considered to be due to the *reversal* of the luminous lines due to the incandescent vapours with which the sun is surrounded The system of luminous lines yielded by many elements, especially the metals of the alkalies and alkaline earths, are very marked in their character , thus a sodium compound volatilised in a spirit flame and examined in the spectroscope shows a brilliant yellow double line , a lithium compound an intense crimson line, a thallium compound a bright green, whilst other elements give spectra almost as characteristic, although less simple The presence of one element does not interfere with the spectrum given by another, so that, by igniting a mixture of salts in a spirit flame, the several metallic elements which it contains can be recognised at once in the spectroscope The delicacy of these spectrum reactions is very great , of sodium the 180 millionth part of a gram can easily be detected, of lithium the 6-millionth part of a gram, and proportionally minute traces of other bodies This method of spectrum analysis is now constantly used in chemical laboratories As it has been proved that the black lines of the spectrum are simply due to the reversal of luminous lines, it is evident that the presence of an element can be just as conclusively proved by recognising its system of black lines as of its bright lines , therefore, by carefully preparing maps of the lines given by the terrestrial and comparing them with the lines of solar, stellar, and other spectra, the terrestrial elements (iron, copper, zinc, nickel, sodium,

&c) are shown to be present in the celestial bodies. For further information on this point see Roscoe on *Spectrum Analysis*, Macmillan, 1869, and also articles *Spectrum; Fraunhofer's Lines, Spectra of the Elements, Metallic Spectra, Spectroscope.*

SPECTRUM, CHEMICAL ACTION OF. See *Actinism.*

SPECTRUM, DARK LINES OF THE See *Fraunhofer's Lines.*

SPECTRUM, ILLUMINATING POWER OF The illuminating power of the solar spectrum attains its maximum in the yellow, and diminishes on each side according to a rapidly descending curve (See *Spectrum*)

SPECTRUM MICROSCOPE Compound microscopes frequently have a spectroscope attached to them, so as to enable the spectrum of the light passing through any object in the field of view to be examined There are two principal forms of spectrum apparatus, in both of which *direct vision prisms* are employed The simplest form consists in fitting a small slit at one end of a tube about three inches long, and a convex lens at the other end, adjusted to distinct vision of the slit, between the two a compound prism is placed, and the whole then becomes a small direct vision *spectroscope*, showing the principal *Fraunhofer lines* when held up to the sky This instrument is arranged to slide over the eye piece of the microscope, and it then gives a spectrum of the light transmitted by any object which is in the field of view A reflecting prism is sometimes fixed beneath one half of the slit, so as to obtain a standard spectrum in the field together with the one under examination One great objection to this form is, that the dispersion is so slight, and, moreover, the eye has to be removed from the instrument when the spectrum apparatus has to be removed Mr Crookes has devised a form of spectrum microscope in which these difficulties are overcome Beneath the principal stage of the microscope is a sub stage carrying a half inch object glass, which throws an image of a slit into the field of view, the slit is carried on a brass slide, by pushing which it can be replaced by a circular aperture admitting a wide beam of light, or a square aperture to be used when searching for *dichroism* Immediately above the object glass is a slider carrying the direct vision prisms which, by a movement of the finger, can be thrown in or out of the field All these parts may be permanently attached to the microscope, as they do not interfere with its ordinary work When, however, it is desired to examine the spectrum of any object which is in the field, the image of the slit is brought in with one touch of the finger and the prisms are pushed in with another, when the spectrum appears, and may be brought to accurate focus by the ordinary rackwork adjustment When ordinary daylight is used, Fraunhofer's lines are clearly visible, and with sunlight the line D can be doubled By using a spirit flame containing an alkaline or alkaline earthy compound, the bright lines are seen as in an ordinary spectroscope In fact, this instrument may replace a spectroscope for most purposes

SPECTRUM OF HYDROGEN See *Hydrogen, Spectrum of, Hydrogen Lines, Broadening of*

SPECTRUM, PHOTOGRAPHS OF THE See *Actinism*

SPECTRUM, PROJECTION OF, ON SCREEN This is now almost invariably effected by means of the electric light, the optical arrangements attached to the lantern are a magic lantern condenser near the carbon poles, adjusted so as to illuminate the slit as much as possible Outside the lantern an achromatic convex lens, either single or compound, receives the light from the slit and brings it to a focus on the screen, where it forms an intensely bright and sharp line of light, whose apparent width may be adjusted by the screw attachments to the slit A prism or prisms now being interposed, the light is refracted and dispersed into a brilliant coloured spectrum If the lower carbon pole is hollowed into the form of a small crucible, metals such as thallium, silver, &c, or alkaline and earthy compounds, such as chloride of lithium, or strontium, &c, can be inserted, and being volatilised by the intense heat, produce an incandescent arc, which will project on to the screen the spectrum characteristic of the substance present (See *Spectrum, Elements, Spectra of the, Metallic Spectra*)

SPECULAR IRON See *Iron, Cast*

SPEISS A name applied to a mixed sulphide and arsenide of nickel, obtained in the manufacture of smalt Nickel is usually procured from it

SPELTER A name sometimes applied to crude metallic zinc

SPERMACETI. A white crystalline fatty substance occurring with sperm oil in the head of the sperm whale It is very soft and brittle, of specific gravity 0 943 It melts at about 40° C (104° F)

SPECULUM (*Speculum*, a mirror.) A highly polished reflecting surface This term is usually confined to the concave reflectors of astronomical telescopes, which are made of speculum metal or silvered glass. In the former case, the alloy is simply ground and polished to a parabolic surface (See *Parabolic Mirror*) In the latter case, a glass surface is polished to a parabolic curve, and metallic silver is then precipitated upon the surface by chemical means, which

is afterwards polished For a discussion of the relative merits of glass and metallic speculæ, see Mr Grubb's paper *Phil Trans*, 1869, p 127.

• SPECULUM METAL An alloy of which the parabolic reflectors of astronomical telescopes are made Lord Rosse's alloy consists of four equivalents of copper to one of tin This is probably the best, and is the one used in the great Melbourne telescope The Rev W T Kingsley adds to this compound one-fourth of an equivalent of zinc

SPHERE, FOCUS OF The distance of the principal focus of a sphere from the circumference varies according to the index of refraction of the substance of which the sphere consists Thus, supposing the sphere to be one inch diameter, the focus would be four feet for tabasheer, whose index of refraction is 1 11145, 1 foot for water, ½ an inch for glass, and nothing for zircon,—that is to say, in a zircon sphere the focus would coincide with the circumference The rule is, divide the index of refraction by twice its excess above unity, and the quotient is the distance from the centre of the sphere to the focus, in radii of the sphere

SPHERICAL LENS A sphere of glass, or other transparent medium, is sometimes called a spherical lens

SPHEROIDAL CONDITION OF LIQUIDS See *Leidenfrost's Experiment*

SPICA *or* SPICA AZIMECH (Arabic) The star α of the constellation Virgo

SPIRAL NEBULÆ See *Nebulæ*

SPIEGELEISEN See *Iron, Cast*

SPOTS ON THE SUN See *Sun*

SPRENGEL'S PUMP An ingenious and excellent invention of Mr H Sprengel for obtaining a perfect or almost perfect vacuum Suppose it were required to exhaust a vessel of air, and that we could put it in communication with the vacuous space left at the top of a tube of mercury more than 30 inches, or of water, more than 32 feet high (see *Torricellian Vacuum*), a certain amount of the air would be drawn out of it into the vacuous space, and the level mercury or water in the tube would fall If, then, the connection with the air vessel were cut off, and if the mercury or water tube were again filled up, and a perfect Torricellian vacuum obtained, on once more connecting the air vessel to the vacuum tube, a second portion of the air would be removed, and by degrees the whole of it might in this way be got rid of This is precisely what Sprengel's pump does in a continuous way In its simplest form it consists of a straight tube, which, if mercury be used, may conveniently be 5 feet long, and if water be employed, ought to be about 40 The lower extremity dips under the surface of mercury or water in a receiving vessel, and to the upper is attached a funnel which is kept full of the liquid A stop cock is inserted between the funnel and the tube, and when the stop cock is open, the liquid flows from the funnel to the receiving vessel below At a point in the tube more than 30 inches, if mercury be used, (or 32 feet if water be employed), from the surface of the liquid in the receiving vessel, there is a lateral opening, from which a small short tube proceeds, and to this is attached by an india-rubber connecting tube, or by corks, or in any other convenient way, the vessel which is to be exhausted The stop cock is then opened, and the liquid permitted to flow down from the funnel As the liquid descends bubbles of air are seen to rush from the vessel to be exhausted, through the lateral tube, into the principal tube, and they are carried forward with the falling column down to the receiving vessel beneath, where, if necessary, they may be collected if the extremity of the principal tube is bent upward into a form convenient for delivering gases When the bubbles of air no longer flow into the mercury tube, the vessel is completely exhausted, and the vacuum obtained in this way is almost as perfect as the Torricellian vacuum

It will be seen from what we have said that the quantity of air removed in each bubble cannot be very great It is, therefore, found convenient, when the vessel to be exhausted is very large, to connect it, in the first instance, with a common air pump, and by means of it to remove the greater portion of the air, then to attach it to Sprengel's pump and complete the exhaustion The description of the pump by Mr. Sprengel will be found in the *Journal of the Chemical Society*, 1865

SPRING See *Seasons*.

SPRING-BALANCE. An instrument by which the intensity of forces is measured by the compression they produce upon springs This principle is applied in many ways In one of these the instrument consists of an elastic bent bar of steel, to the ends of which metallic graduated arcs are attached. The outer arc, fixed to the lower portion of the bar, passes through an aperture in the upper portion, and terminates in a ring, by which the instrument is supported The inner arc is attached to the upper arm, passes through the lower arm, and has a hook at its extremity to which a weight can be fastened The instrument is graduated by means of standard weights, which, when suspended from the hook, cause the two portions of the steel band to approach each other till the elastic force of the steel counterbalances the weight.

The extent to which the outer arc is caused to project beyond the upper part of the bar by different weights, determines the points of graduation for the corresponding intensities of force, and thus forces of many kinds can be expressed in terms of the unit of weight. Whenever a spring balance is applied to compare different kinds of forces, it forms a *dynamometer* (See *Dynamometer*). Spring balances capable of measuring very large forces can be constructed, and applied to such purposes as that of measuring the force with which a horse draws a carriage along a road. Another form of spring balance has the weight attached to the exterior of a hollow metal cylinder in which a spring is coiled. The spring is compressed by the rod of suspension, which is connected with the lowest part of the spring. The rod is graduated according to the extent of its rise out of the cylinder.

STABLE EQUILIBRIUM. See *Equilibrium*.

STABILITY (*Stabilis*, able to stand, from *stare*, to stand). See *Equilibrium*, and *Gravity, Centre of*.

STANDARD (ABSOLUTE) OF LENGTH, TIME, AND MASS. Professor J. Clerk Maxwell, F.R.S., in his address to the mathematical and physical section of the British Association (Liverpool meeting), held in September 1870, threw out the suggestion that, if we wish to find an absolutely unchangeable standard of length, time, and mass, we have it in a molecule of hydrogen; for when agitated by heat or by the passage of the electric spark, these molecules vibrate precisely in the same periodic time. Not only has every molecule of terrestrial hydrogen the same system of periods of free vibration, but the spectroscopic examination of the light of the sun and stars shows that in regions, the distance of which we can only feebly imagine, there are molecules vibrating in as exact unison with the molecules of terrestrial hydrogen as two tuning-forks tuned to concert pitch. If, then, we wish to obtain standards of length, time, and mass, which shall be absolutely permanent, we must seek them, not in the dimensions or the motion or the mass of our planet, but in the wave length, the period of vibration, and the absolute mass of these imperishable and unalterable, and perfectly similar molecules.

STANNATES. Combinations of binoxide of tin or stannic acid (see *Tin*) with bases are called stannates. The following are the most important:—*Stannate of potassium* ($K_2O\,SnO_2\,3H_2O$) separates from its solutions in hard transparent crystals, of specific gravity 3.2, readily soluble in water, but insoluble in alcohol. *Stannate of sodium* ($Na_2O\,SnO_2\,3H_2O$) crystallises in large hexagonal plates, which are very soluble in cold water, but much less so in hot. Both the sodium and potassium salts are much used in calico printing and dyeing.

STANNIC ACID. See *Tin, Binoxide*.

STAR (ἀστήρ, ἄστρον). All the discrete luminous bodies which lie beyond the outermost bounds of the solar system are called in astronomy *stars*. The nearest of these bodies is yet removed to a distance so enormous that the earth's orbital motion around the sun produces no obvious change in the star's position. Nor are any of these external orbs subject to motions great enough to cause them to shift their places in an obvious manner. Hence these orbs are called the *fixed stars*, to distinguish them from the *planets* whose positions on the sky vary obviously, both on account of the earth's and their own motions.

Nomenclature of the Stars. One of the earliest works undertaken by the astronomer must have been the formation of a system by which the fixed stars could be distinguished one from the other. To this end groups of stars were compared to various animals and other objects (see *Constellations*), and the separate stars were referred to according to their positions in these figures, while the more conspicuous orbs received special names. But this method was cumbrous and inconvenient; and as the number of observed stars increased, it became absolutely necessary to invent a more effective system of nomenclature. The plan in use at the present time is the one which in effect replaced the inconvenient nomenclature of the ancients; and it affords striking evidence of the difficulty of effecting improvements in this particular branch of astronomy, that the modern system should have come so late into use, as well as that it should be retained, now that astronomy has made such important advances in other respects. According to this plan, the stars belonging to each constellation were distinguished by the letters of the Greek alphabet, the brightest by the letter α, the next by the letter β, and so on in order. When the Greek letters were exhausted, the Roman letters followed in order, and then the Italian. It would not seem that Bayer was very careful as regards the sequence of the stars in order of brightness; but there can be no doubt that, in many instances, the apparent want of correspondence between the order of brightness and the order of Bayer's lettering is due to a real change in the brightness of many stars since his day. The next mode of indicating the stars which has to be noticed is that employed by Flamsteed. This astronomer numbered the stars in each constellation in the order of their right ascension, including in the list all the stars whose places he had observed and recorded. Thus many stars invisible to the naked eye appear in Flamsteed's list. His numbers are given to stars which Bayer had already lettered, as

well as to others left unnamed by Bayer Thus many stars have two distinct appellations, a source of obvious confusion In some instances it has even happened that the two names of a star actually refer it to different constellations Thus, the star which Bayer called ξ Scorpii is called by Flamsteed 51 Libræ The eminent observer Piazzi arranged the stars he observed in hours of right ascension, numbering them in order of R A throughout each hour Thus the star 230 XV is the 230th in order of R A within the 15th hour of right ascension This arrangement, like all depending on the position of a star in right ascension and declination, has the disadvantage of being rendered practically unintelligible through the changes produced by the precession of the equinoxes The use of Roman and Italic letters has been adopted on a somewhat anomalous plan In the constellation Argo, Roman capitals and Italic common letters are employed to indicate stars belonging to the subdivisions *Velo*, *Malus*, *Carina*, and *Puppis* Elsewhere small Italic letters are occasionally employed, as well as Roman capitals belonging to the first part of the alphabet But everywhere, except in Argo Roman capitals belonging to the latter part of the alphabet (beginning with R), are employed to indicate the variable stars of a constellation in the order of their discovery

Undoubtedly it would be most advantageous if a system of nomenclature could be devised by which all the anomalies of the present arrangement could be removed The irregular and continually varying figures of the constellations suggest that, as regards the division of the heavens into small parts, a wholly new plan should be adopted Again, the changes resulting from precession, render a reference either to right ascension and declination, or to longitude and latitude, inconvenient What is obviously wanted is the division of the heavens according to a uniform plan, depending on the features actually presented by the sidereal system The galactic zone affords a natural circle of reference, and a system of division and nomenclature referred to that circle would have the important advantage of being liable to no changes, save those resulting from the proper motions of the stars, which would not (for this purpose) appreciably affect the heavens for thousands of years to come Even when changes were thus rendered necessary, they would be unimportant (if the original plan of division had been well devised) and easily effected

Distribution of the Stars There are few subjects which are better worthy of study than the laws regulating the distribution of the stars (1) over the celestial sphere, and (2) throughout space On the second point we must be guided for the present rather by inferences derived from appearances, than from any exact information we possess, or can hope to possess It is from the study of the distribution of the stars over the heavens that we must proceed to the deduction of such inferences Turning to the heavens, then we recognise at a first view a wonderful irregularity of stellar distribution Along a zone of the heavens we see a region of diffused light which has been found to consist wholly of stars Elsewhere this diffused light is for the most part wanting, but it is seen again in the two Magellanic Clouds, while, in certain parts of the heavens, clustering aggregations of greater or less extent attest the existence of laws of association, which may be supposed somewhat to resemble those to which the Milky Way owes its origin Towards the neighbourhood of the Milky Way we find the visible stars more richly aggregated, while, in certain of the richer parts of the galaxy, they are gathered into groups and clustering aggregations, whose richness is significant of a real association between the Milky Way and the lucid stars seen within its limits It may be remarked in passing, that, in treatises on popular astronomy, a statement made by Sir John Herschel is quoted very frequently, without its real purport being adequately recognised He remarks that, "if we confine ourselves to the three or four brightest classes, we shall find them distributed with a considerable approach to impartiality over the sphere, a marked preference being observable, however, especially in the southern hemisphere, for a zone or belt following the direction of a great circle passing through ε Orionis and α Crucis But if we take the whole amount visible to the naked eye, we shall perceive a great increase of number as we approach the borders of the Milky Way, and, when we come to telescopic magnitudes, we find them crowded beyond imagination, along the extent of that circle, and of the branches which it sends off from it" It is a matter of so much importance as regards the views we are to form respecting the real nature of the stellar system, that we should quite clearly ascertain whether the visible stars do indeed show any sign of affecting the neighbourhood of the Milky Way, that it is necessary to quote another passage from Sir John Herschel's writings, pointing to a result directly opposed to that stated above In his "Observations made at the South Cape," he remarks, as the direct result of a careful statistical inquiry into the laws of distribution observable among the fixed stars, that "the tendency to greater frequency, or the increase of density in respect of statistical distribution in approaching the Milky Way, is quite imperceptible among stars of a higher magnitude than the eighth, and except, on the very verge of the Milky Way itself, stars of the 8th magnitude can hardly be said to participate in the general law of increase For

the 9th and 10th, the increase, though unequivocally indicated over a zone extending at least 30° on either side of the Milky Way, is by no means striking It is with the 11th magnitude that it first becomes conspicuous, though still of small amount when compared with that which prevails among the mass of stars of magnitudes inferior to the 11th, which constitute 16-17ths of the totality of stars within 30° on either side of the galactic circle" The real explanation of the seemingly contradictory results here indicated, lies in this, that, taking the Milky Way in detail, the lucid stars exhibit a real association with its configuration, a real tendency to aggregate over its extent, and near its borders, but taking "zones of galactic polar distance," as Sir John Herschel has done in the inquiry on which the second of the above results is founded, this tendency is lost sight of It is by studying details, not by studying averages, that the true relation is made to appear Of the necessity of carefully attending to this distinction, the following quotation bears evidence Immediately after exhibiting the results above cited, Sir John Herschel adds, "Two conclusions seem to follow inevitably from this, viz —1st, That the larger stars are really nearer to us (taken *en masse*, and without denying individual exceptions) than the smaller ones Were this not the case, were there really, among the infinite multitude of stars constituting the remoter portions of the galaxy, numerous individuals of extravagant size and brightness, as compared with the generality of those about them, so as to overcome the effect of distance, and appear as large stars, the probability of their occurrence in any given region would increase with the total apparent density of stars in that region, and would result in a preponderance of considerable stars in the Milky Way, beyond what the heavens really present over its whole circumference Secondly, That the depth at which our system is plunged in the sidereal stratum constituting the galaxy, reckoning from the southern surface or limit of that stratum, is about equal to that distance which, on a general average, corresponds to the light of a star of the 9th or 10th magnitude, and certainly does not exceed that corresponding to the 11th" Both these important conclusions must inevitably be dismissed, and the converse of the first must inevitably be accepted, if it appears that the lucid stars exhibit a real increase of richness in the neighbourhood of the galaxy, and over its branches and convolutions As very little doubt can exist on this point when we study the aspect of the heavens, to the naked eye, or the relations presented in well-constructed star maps, and as, in fact, Sir John Herschel himself recognises the existence of such a law of stellar aggregation, we are led to the conclusion that the bright stars seen in the galaxy are really involved amid richly aggregated groups of relatively minute stars

There are other laws of stellar distribution which require to be considered, in endeavouring to form a just opinion of the real distribution of stars throughout space It has been discovered by the present writer that, in the northern heavens, there is a marked tendency among the lucid stars to aggregate within a nearly circular region, covering the constellations Cygnus, Cepheus, Cassiopeia, Lacerta, Ursa Minor, and part of Draco Within this region, which covers about one-fourteenth part of the heavens, about an eighth part of the stars visible to the naked eye are collected In the southern hemisphere a larger region of similar shape exists It has the greater Magellanic Cloud nearly in its centre, and extends about 45 degrees in every direction from that centre It covers about a sixth part of the heavens, and contains nearly a third part of all the stars visible to the naked eye

Smaller regions rich in stars exist, and there is a sort of orderly sequence from regions rich in stars to closely crowded groups, clusters of gradually increasing density, &c, down to the irresolvable nebulæ (See *Clusters*, *Nebula*, &c)

Number of Stars According to Argelander the total number of observed stars visible to the naked eye in the northern hemisphere is 2342 The southern hemisphere is richer by upwards of 1000 stars Perhaps the most complete list of visible stars is that included in the British Association Catalogue There are in this catalogue 5932 stars of magnitudes 1–6 inclusive, and of these about 2400 fall within the northern hemisphere

When we pass beyond the limits of visibility, and consider the numbers of the telescopic stars, we find ourselves perplexed by the contradictory accounts given by different astronomers Struve, from a careful study of Sir William Herschel's star-gauges, estimates the total number of stars within the range of Herschel's twenty feet reflector at upwards of 20 millions But Chacornac estimates the stars of the first 13 magnitudes at 77,000,000 Of stars not exceeding the 9th magnitude, upwards of 300,000 have already been catalogued

Distances of the Stars Our information respecting the absolute distances of the fixed stars is very meagre We know the distance of one star pretty certainly, and we have formed tolerably clear conceptions of the distances of some four or five others (though in all these instances the relative limits of error are very great), but, further than this, we have no trustworthy information The following list includes all the instances in which stars have been found to exhibit an annual displacement due to the earth's annual revolution in her orbit, as also the amount of such displacement, and the names of the investigators .—

α Centauri,	0 976″	(Henderson, corrected by Maclear)
61 Cygni,	0 348	(Bessel)
Lalande, 21258,	0 260	(Kruger)
Oeltzen, 17415-6,	0 247	(Kruger)
α Lyræ,	0 155	(W Struve, corrected by O Struve)
Sirius,	0 150	(Henderson, corrected by Peters)
70 Ophiuchi,	0 160	(Kruger)
ι Ursæ Majoris,	0 133	(Peters)
Arcturus,	0 127	(Peters)
Polaris,	0 067	(Peters)
Capella,	0 046	(Peters.)

With the exception of the first in the list, all these determinations remain open to grave question, and the last four or five must be regarded as altogether unreliable

Now, in considering the real meaning of these results, it is to be remembered that a parallax of one second implies a distance exceeding the radius of the earth's orbit no less than 206265 times, or regarding the actual distance of the earth from the sun as in all probability about 91,500,000, we obtain as corresponding to a parallax of 1″, a distance of no less than 18,873,247,500,000 of miles All the stars of the above list, therefore, lie at distances exceeding this enormous range We may take the distance of α Centauri as about 20 billions of miles, the distance of the other stars greater in proportion as their parallaxes are less "In such numbers," as Sir John Herschel justly remarks, "the imagination is lost The only mode we have of conceiving such intervals at all, is by the time it would require for light to traverse them" It is readily calculable that light would occupy about 3½ years in travelling to us from α Centauri, and about 9½ in reaching us from 61 Cygni, supposing the distance of that star to be accurately represented by the estimate which Bessel has formed

With respect to the distances at which other stars lie from us, the present writer finds himself unable to accept the general conclusions which have hitherto been adopted by astronomers The smallness and close crowding of stars within the Milky Way does not appear to him to afford satisfactory evidence of the relative vastness of their distance On the other hand, he recognises the probability, nay, the absolute certainty, that among the countless millions of stars revealed by the telescope, a considerable proportion must be as large as Sirius, Canopus, or Arcturus, while some may even be far larger Hence the distances of many stars must be as vast as those accorded by the accepted theories to the faintest galactic stars, if not in several instances far vaster There would seem, too, to be no limits to the range of distance within which our telescopes, let then powers be increased as greatly as they may, will reveal stars to us

Magnitude of the Stars Owing to the circumstance that the most powerful telescope does not exhibit the real disc of a star, it is impossible to form any estimate from actual measurement of the dimensions of even the largest star All, therefore, that can be done towards the determination of this element is to compare the amount of light received from a star whose distance is known, with that given by the sun, and then, on the assumption that the intrinsic brilliancy of the star is not very different from that of the sun, we can tell what the sun's light would be if he were removed to the star's distance, and so the proportion in which the dimensions of the star exceed or fall short of those of the sun To apply this method, for instance, to the case of Alpha Centauri, the star whose distance has been most satisfactorily determined, we proceed as follows The distance of Alpha Centauri exceeds about 230,000 times the distance of the sun. So that if the sun were removed to the star's distance he would shine with only one 52,900,000,000th part of his actual lustre Now, by considering Sir John Herschel's comparison between the light of Alpha Centauri and that of the full moon, and Zöllner's comparison between the light of the full moon and that of the sun, it can readily be shown that the light we receive from the star is about one 16,950,000,000th part of that which we receive from the sun Thus the star emits about three times as much light as the sun, and the disc of the star being, therefore, assumed to be about three times as great as that of the sun would be if removed to the same distance, it follows that the diameter of the star exceeds that of the sun in the proportion of about $\sqrt{3}$ to 1, or as 17 to 10 If we could as confidently rely on the estimates of the distance which separates us from Sirius it would appear that the amount of light emitted by this star exceeds that emitted by the sun about 192 times Thus the diameter of Sirius would appear to exceed that of the sun in the proportion of about 14 to 1, and the volume of Sirius would appear to exceed that of the sun no less than 2688 times!

Proper Motions of the Stars See *Proper Motions*

For accounts of double stars, variable stars, &c, see under these respective heads.

STARCH A substance of constant occurrence in the vegetable kingdom It is chemically one of the carbo-hydrates, or bodies containing carbon, and oxygen and hydrogen in the proportion to form water Composition $C_6H_{10}O_5$ It is a white glistening powder, which when pressed in the hand has a peculiar grating feel Under the microscope it is seen to possess organisation, consisting of a nucleus surrounded by concentric envelopes Examined with polarised light it shows a black cross It is insoluble in cold water, but in hot water it disintegrates and forms a jelly Starch is coloured blue by iodine, under the influence of heat or dilute acids it is converted into dextrin and sugar

STAR GAUGING A plan by which Sir William Herschel hoped to be able to form an estimate of the figure of the sidereal system It consisted in counting the number of stars seen in the field of view of one of his 20-feet reflectors, and founding on that number an estimate of the extension of the system in the direction towards which the telescope was turned. It is founded on three assumptions First, that light suffers no appreciable extinction on its course through space secondly, that the telescope employed could render visible stars at the outermost limits of the galaxy, and, thirdly, that the stars are not so greatly disproportioned in magnitude that any considerable proportion of them within the limits of the sidereal system would be invisible in the 20-feet reflector through relative minuteness All three assumptions may very fairly be questioned (See *Galaxy*)

STARS, COLOURED Among the stars visible to the naked eye there are many which exhibit well-marked signs of colour, especially of colour belonging to the red end of the spectrum For instance, Antares, Aldebaran, and Betelgeux, are ruddy, Arcturus, Procyon, and Pollux, yellow, while Capella and Sirius are brilliantly white, and Vega and Altair are of a bluish white tint It is, however, among the telescopic stars that the most marked instances of colour occur In many parts of the heavens stars of a deep red are found, some even approaching to blood colour Ruddy, orange, orange yellow, and yellow stars are also found, their hue being in many instances far more pronounced than in the case of any of the lucid orbs Strangely enough, among the single orbs there are no well marked instances of colours belonging to the blue end of the spectrum When we consider the double and multiple stars we find not only the colours already noticed among single stars, but blue, green, indigo, violet, and lilac stars, besides such tints as gray, fawn, ash colour, russet, olive, and other hues which one would hardly expect to find among celestial orbs It has been supposed that in many of these instances the colour may be due to some effect of contrast For example, where a bright red star has a small green companion, or where a bright orange star has a small blue companion (and many such instances of the association of complementary colours exist among the double stars) it may be conceived that the colour of the smaller orb is merely due to the law of contrast by which faint lights appear to be tinged with the colour complementary to that of neighbouring bright lights But it has been experimentally demonstrated that this explanation is not, at least in the great majority of instances, the true one For it has been found that when the brighter of two such associated orbs is concealed from view the fainter retains its colour either altogether unchanged or but little diminished

Many interesting considerations are suggested by the contemplation of coloured double stars If each of the components of a double system has its own system of dependent worlds, how strange must be the relations presented to beings whose own special sun is green or blue, for example, while a neighbouring sun, large enough to produce a large proportion of the light they enjoy, is red or orange To use the words of Sir John Herschel, "It may be more easily suggested in words than conceived in imagination what variety of illumination two suns—a red and a green, or a yellow and a blue one—must afford a planet circulating around either, or what charming contrasts and 'grateful vicissitudes'—a red and a green day, for instance, alternating with a white one and with darkness—might arise from the presence or absence of one or other or both above the horizon" Nor are relations of less interest suggested when we consider the possibility that the dependent worlds belonging to such a system may be far removed from both suns and circle around their common centre of gravity

STARS, DOUBLE AND MULTIPLE It was discovered, soon after the invention of the telescope, that many stars which to the naked eye appear single are in reality double It is commonly asserted that the first double star actually noticed was the star Mesartim or γ Arietis, and its discoverer Dr Hooke, but the assertion is open to considerable doubt At first it was supposed that the duplicity of such stars merely arises from the accidental appearance of two stars nearly on the same visual line But an inquiry of great interest, belonging to another branch of astronomy, led to the recognition of the fact that most of the double stars are really pairs of physically associated bodies The idea occurred to Sir William Herschel (not, as is commonly asserted to Galileo) that by observing close double stars, means might be found of determining with great accuracy the effects of the earth's motion in causing an apparent change

in a star's position, and that thus the distance of the star might be determined For where two stars, very close together, are very unequal, it might be assumed, he thought, that the smaller lies far out in space beyond the larger Thus the annual parallax of the smaller would be very much less than that of the larger, and might in many cases be regarded as practically insensible Hence all that would be necessary to determine the distance of the larger star would be to determine accurately its apparent changes of position with respect to the smaller This would obviously be a much simpler and easier task than the detection of its absolute apparent changes of position But while engaged in attempting to apply this simple method to the solution of a very difficult problem, Sir William Herschel was startled by a discovery of an unexpected character He found that in several instances the smaller of two associated stars was actually revolving around the larger, in other words that the two bodies formed a pair or system It was not till 1803 that he announced this discovery definitely to the world It was received with considerable doubt, partly because the idea itself was so surprising, partly because the result seemed to oppose the cherished doctrine that the stars are distributed uniformly throughout space But continued observation justified fully the theory put forward by Sir William Herschel None have distinguished themselves more in researches directed to the vindication of Herschel's views than his son Sir John Herschel, Sir James South, and William Struve, the eminent Prussian astronomer The last named astronomer in particular has largely extended the list of known binaries (Herschel and South, Phil Trans, 1826, Herschel, Memoirs of the Royal Astronomical Society, vol iii, Struve, Catalogus Stellarum Duplicium et Multiplicium, 1837) Among the most remarkable binaries may be mentioned γ Virginis, ζ Ursæ Majoris, 70 Ophiuchi, Castor, 61 Cygni, ϵ Hydræ, and ζ Aquarii

But besides double stars the heavens present to our contemplation triple, quadruple, quintuple, and multiple systems, exhibiting every variety of magnitude, position, motion, and colour Assured by the proof that really associated pairs of stars exist within the sidereal system, astronomers have found themselves able to accept the view that these higher orders of association are in many cases real also

Among double, triple, and multiple stars are seen many striking instances of rich or contrasted colours (See *Stars Coloured*)

STARS, SPECTRA OF As a general rule the spectrum of the fixed stars is similar to that of our sun, consisting of a bright spectrum crossed with black lines of all degrees of intensity and thickness In many of the stars lines occur in the same positions as some of those in the solar spectrum, and are probably due to the presence of the same element, most of the dark lines, however, have not been identified A few stars give bright lines (See *Variable Stars, Spectra of*, *Coloured Stars, Spectra of*)

STARS, TEMPORARY Amongst the most remarkable phenomena presented by the heavens to man's contemplation must be ranked the appearance of new stars and the disappearance of those which have found a place in our charts and catalogues About the year 125 B C, a new star appeared, which was so bright as to have been visible in the daytime Hipparchus was induced, it is said, by the appearance of this object to draw up his catalogue of stars Another star appeared near α Aquilæ in the year 389 of our era, "remaining," says Sir John Herschel, "for three weeks as bright as Venus, and then disappearing entirely" In the years 945, 1264 and 1572, brilliant stars made their appearance in the part of the heavens between Cepheus and Cassiopeia, and Goodricke was led to suspect from the near equality of the intervals separating the apparitions, that they were in reality but successive appearances of the same star If so, we may shortly look for its reappearance The apparition in 1572 was very sudden Tycho Brahe asserts his conviction that half an hour before the time when his attention was first directed to the new star it had not been visible It was as bright when first seen as Sirius, and increased in lustre until it surpassed Jupiter when he is in opposition But in December 1572 it began to diminish, and by March 1574 had disappeared Another new star, also very brilliant, made its appearance in the constellation Serpentarius, on October 10, 1604, and continued visible until October 1605 In 1670 a new star appeared in Cygnus, and on April 28, 1848, Mr Hind discovered a new star of the fifth magnitude in the constellation Ophiuchus Both these orbs eventually vanished

It is doubtful whether we should associate the star Eta Argûs with the class of objects now under consideration, or with the periodical stars In 1677 it was recorded by Halley as a star of the fourth magnitude In 1751 Lacaille observed it to be of the second magnitude Between 1811 and 1815 it was again of the fourth magnitude, and again from 1822 to 1826, of the second On February 1, 1827, it had increased to the first magnitude, and was as bright as α Crucis But it presently returned to the second magnitude, and so remained until the year 1837 In the beginning of 1838 it increased in brightness until it was nearly equal to α Centauri (the third star in the heavens for brightness). Then it diminished but not below the

magnitude, until 1843, in April of which year it increased again until it nearly equalled Sirius itself in splendour" In May 1863 it was scarcely visible to the naked eye, and now in the year 1870, though it seems to be slowly recovering its lustre, it is still only of the sixth magnitude

On May 12, 1866, a new star of the second magnitude was discovered by Mr Birmingham, of Tuam, and somewhat later, but independently, by Mr Baxendell, of Manchester, in the constellation Corona Borealis It decreased rapidly in splendour, insomuch that by May 20 it had already fallen below the sixth magnitude It sank to the 10th magnitude, but rose again to the seventh, and has exhibited since some singular fluctuations as a telescopic star

STARS, VARIABLE, or PERIODICAL There are many stars which vary periodically in brightness Amongst these the following are the most remarkable —Algol, in the constellation Perseus, is usually seen as a star of the second magnitude, but for about 7 hours in every successive interval of 69 hours it exhibits a gradual decrease to the fourth, and then a gradual increase to its original magnitude, the decrease and increase occupying about the same time The star β Lyræ is another remarkable variable Its period is about 12d 22h, in which time, however, it goes through a double change, resulting in an apparent variation within 6d 11h, which was supposed by the earlier observers to be the true period of this singular variable The two maxima are equal, the star increasing to about the 3 5 magnitude during both periods but the minima are appreciably unequal, the magnitude of the star being 4 3 during one and 4 5 during the other Besides this peculiarity the variation of the star exhibits a strange change of period The period continually lengthened from 1784, when Goodricke discovered the variability of the star until 1840, but since the latter epoch the period has been slowly diminishing

The star δ Cephei is another remarkable variable It was first recognised as a variable by Goodricke in 1784 Its period is 5d 8h 48m, during which time it varies from the fifth to between the third and fourth magnitudes The most striking feature of its variation is the fact that while it occupies only 1d 14h in increasing from its minimum to its maximum brightness, the interval during which it is diminishing is no less than 3d 19h But perhaps the most remarkable of all the systematically variable stars is the star Mira Ceti (o Ceti) first recognised as a variable by Fabricius in 1596 Its period of variation is about 331d 8h 4m 16s It shines for about a fortnight as a star of the second magnitude, decreases during about three months, at the end of which time it is altogether invisible, remains invisible for five months, and then increases during the remaining 2¼ months of its period "Such," says Sir John Herschel, "is the general course of its phases It does not always, however, return to the same degree of brightness, nor increase and diminish by the same gradations, neither are the successive intervals of its maxima equal From the recent observations and inquiries into its history by M Argelander, the mean period above assigned would appear to be subject to a cyclical fluctuation, embracing 88 such periods, and having the effect of gradually lengthening and shortening alternately those intervals to the extent of 25 days one way and the other The irregularities in the degree of brightness attained at the maximum are probably also periodical" It is remarkable that this star when near its minimum changes colour from white to a full red, a peculiarity which promises to afford a means of answering some of the perplexing questions suggested by the periodical variability of the stars It is noteworthy of Mira Ceti, that it does not at every return to its maximum become equally bright For example, Hevelius tells us that during the four years between October 1672 and December 1676, Mira did not appear at all On October 5, 1839, on the other hand, it outshone α Ceti and β Aurigæ, both of which usually surpass Mira even when at its maximum A similar peculiarity is observed in the case of the star χ Cygni (Smyth thus names a star which is not variable, but Baxendell has shown that the variable in the neck of Cygnus is the star which should be called χ), which at the period of its maximum has sometimes been invisible, as in 1699, 1700, and 1701, though usually of the fifth magnitude at such times

The principal recent observers and discoverers of variable stars have been Hind, Baxendell, Schmidt, Sir J Herschel, Pogson, and Chacornac

STATICS That branch of mechanics which considers the relations of forces which act upon bodies at rest

STEAM The elastic fluid into which water is converted by heat In order to explain the nature of the force arising from steam, let us suppose a cylinder, containing a small quantity of water, to be placed over a heating apparatus, let the cylinder be fitted by a piston, and let the piston be balanced by a weight attached to a cord which passes over a pulley, also let a thermometer be inserted in the water below the piston to measure its temperature Suppose the temperature to be at first 0° Centigrade, or 32° Fahrenheit, and no air to be between the piston and the water To make the piston rise, it will be necessary to overcome the pressure of the atmosphere, which will be about 15 lbs. on the square inch. When heat is applied at the

bottom of the piston, the water in the cylinder rises in temperature until the thermometer reaches 100° C., or 212° F. After this the water will remain at the same temperature, but its volume will diminish, and at the same time the piston will be gradually lifted away from the water. A certain quantity of water will have become steam. When the volume of water has been diminished by 1 cubic inch, 1700 cubic inches of steam will have been produced. If heat be communicated for a sufficiently long time, the whole of the water will become steam, and if the cylinder be large enough to contain it, will occupy 1700 times the space it occupied when in the condition of water. If the lamp or source of heat be removed, the piston will begin immediately to descend, drops of water will be formed on the sides of the cylinder, and will run to the bottom until all the steam has returned to the form of water. By comparing the time taken by the water to rise from 0° to 100° C. with the time which elapses from the commencement of the formation of steam to the instant at which the whole of the water has been transformed, it is found that $5\frac{1}{2}$ times as much heat was required to evaporate the whole as was used in raising the temperature from 0° C. to 100° C. (See *Latent Heat*.) If the area of the cylinder be 1 square inch, and a cubic inch of water be turned into steam, the piston will be raised 1700 inches. The pressure of the air on the piston will be 15 lbs. Consequently, in the conversion of one cubic inch of water into steam, work will be done equivalent to the raising of 15 lbs. through a height of 1700 inches, that is, to 2125 foot pounds.

Experiments to ascertain the relation between the temperature and pressure of steam were made by Watt, and afterwards by Southern his assistant, and an elaborate empirical formula was constructed by Southern from the results of his experiments to determine the pressure of steam at any given temperature. The subject was further investigated by Arago and Dulong, but the latest experiments in the matter are those of Regnault, who has shown that the total amount of heat in a given weight of steam increases with the pressure. When more heat is applied to steam than is required to keep it in the form of vapour, it observes the same laws as other gases. Thus, when the temperature remains the same, the pressure varies inversely as the volume; and when the pressure remains the same, the volume increases for every degree of temperature by $\frac{1}{273}$ of the volume at 0° C.

STEAM BOILER. The apparatus in which water is turned into steam for the purpose of supplying steam engines. The form of boiler introduced by Watt was termed the *waggon*, from the fact that the section of it represented in figure the section of a waggon covered with a semi-circular awning. The waggon boiler is now rarely used, as others are constructed having a higher evaporating power, in proportion to the amount of fuel used, and because the best authorities condemn it as unsafe, especially for steam of a high pressure. The boilers best suited for the purpose are cylindrical. One form much approved, as being both safe and economical, is the Cornish boiler, so named from its general use in the mines of Cornwall. The furnace is not below the boiler as in the waggon, but within it, the flames and hot air passing along a flue to the further end, then back along the sides; next, they return below, and finally escape to the chimney. The Cornish boiler is remarkable for the small amount of fuel burnt in a given time. The tubular boiler is one which is rapidly coming into extended use, and is always employed in the locomotive. It is traversed by straight horizontal tubes, connected on one side with the furnace and on the other with the chimney. The hot air passes from the furnace through these tubes, so that a very large surface is heated in contact with the water.

The following is a comparison of the three kinds of boilers:—

	Waggon	Cornish	Locomotive
Fuel burnt per hour on a square foot of grating,	10.75 lbs.	3.46 lbs.	79.33 lbs.
Square feet of surface required to evaporate one cubic foot of water in an hour, . .	9.96	69.58	6.06

Boilers are supplied with water on two plans: the first consists of a feed pipe, with a cock opened and closed by means of a lever to which a float is attached; the second consists of a contrivance for forcing the water directly into the boiler by means of a force pump, together with a means of regulating the supply according to the requirements of the boiler by a float and lever, forming what is termed the *differential feed*.

Marine boilers usually consist of a number of metallic furnace chambers, with either flues or tubes traversing the boiler, and delivering into the chimney. As these boilers cannot be set in brickwork, they are so constructed that the metallic surfaces which come in contact with the fire and heated air are everywhere surrounded with water. The consumption of fuel in marine boilers, as at present constructed, is very great, amounting to 5 or 6 lbs. per horse power

These boilers are fed of course with salt water, and in order to prevent the salt from being deposited as a hard stony coating, the water has to be driven out before it reaches the density at which the salt is deposited. Hydrometers are now used by the engineers to test the density of the water, and when they indicate that the water is nearly saturated with salt, it is blown out and fresh water introduced from the hot well or the sea.

The explosions of boilers generally arise from one of two causes, either the boiler was not constructed originally of sufficient strength to bear the pressure of the steam, or, in consequence of an insufficient water supply, the flues have become red hot, and unable therefore to sustain the pressure. To prevent the steam from acquiring a greater pressure than the boiler safely bears a safety-valve is attached. (See *Safety Valve*.) Additional information will be found in *Steam Boilers*, by R. Armstrong, C.E., and Bourne's *Catechism of the Steam Engine*, and *Hand book of the Steam Engine*.

STEAM ENGINE. A machine for converting heat into work by means of the elastic force produced when water is changed into steam. The first steam engine on record is the Eolopyle (*Æolus*, the God of the Winds, and *pila*, a ball) of Hero of Alexandria, who lived about 120 B.C. This machine consisted of a hollow globe containing water capable of turning about a horizontal axis, and having two bent tubes with small apertures inserted in a plane perpendicular to the axis at its centre. When the globe was heated the steam escaped from the tubes, and by its reaction caused the globe to revolve. Porta (1580), De Caus (1615), and Worcester (1663), conceived independently the idea of employing the pressure of steam to raise water. Subsequently (1698) Captain Savery took out a patent for a machine on the same principle for raising water from a mine. In 1690 Papin thought of using steam to raise a piston, and in 1705 Newcomen constructed an engine worked by a piston moving in a cylinder. The steam from the boiler passed to the lower part of the cylinder and raised the piston. The steam was then cut off, and a jet of cold water sent into the cylinder so as to condense the steam contained in it. The upper part of the cylinder communicated with the air, consequently, after the condensation of the steam, the atmospheric pressure and its own weight brought down the piston. The communication with the boiler was then renewed, and the whole action repeated. In 1763 James Watt of Glasgow, while repairing a Newcomen engine, conceived, and by laborious study realised improvements which constitute the chief features of the modern steam engine. The improvements which have immortalised the name of Watt are the following:—

1. In order to avoid the waste of heat consequent on the alternate heating and cooling of the cylinder, Watt introduced a condenser apart from the cylinder. When the piston reached its highest point, therefore, he opened a communication between the lower part of the cylinder and a separate chamber into which a jet of cold water was made to play.

2. Watt also introduced an air-pump into the condensing chamber to remove the heated water and air.

3. Another improvement was the *double action* on the piston. The steam was introduced above and cut off from below when the piston was required to descend, and the communication above was closed and that below opened when the piston had to ascend.

4. Watt also introduced the plan of cutting off the steam before the piston reached its limiting position, so that its momentum should be destroyed gradually, and not by a sudden percussion at the end of the stroke.

In Watt's engine, therefore, the course and action of the steam will be as follows:—The steam from the boiler passes along the steam pipe to the valve casing, from whence it is distributed, as it is termed, to the upper and under sides of the piston, producing its alternate up-and-down motion in the cylinder. After working the piston, the steam passes by a pipe to the condenser, where it is condensed by coming in contact with a jet of cold water. From the condenser the water of condensation, together with the air which obtains admission through the steam, and which, if allowed to accumulate, would ultimately prevent the engine working, is drawn off by an air pump, and delivered to a hot well. An arrangement of valves prevents the water from returning to the air pump from the cistern, and also prevents the water which may remain at the bottom of the air pump from being again forced into the condenser on the down stroke of the air pump piston. The condenser and air pump are placed in a cistern filled with cold water supplied by the pump. The jet of cold water which plays over the condenser is supplied from the cistern, and is regulated by a stop-valve.

The piston rod is connected with the end of the working beam, and is kept parallel by a beautiful arrangement of levers, termed Watt's parallel motion. The other end of the beam is joined to the upper end of the connecting rod, which, at its lower end, is attached to the crank. To equalise the motion, a heavy wheel, the fly wheel, is keyed on to the crank shaft. In the revolution of the crank there are two positions, called the dead points, at both of which

the power of the engine has no effect in causing revolution, namely, when the piston is at the terminations of the up and down stroke. By the momentum acquired by the fly-wheel, while receiving the full power of the engine, the crank is carried past its dead points

The arrangement by which the steam is alternately led into the upper and lower part of the cylinder is termed a slide valve The engine itself regulates the motion of the slide valve by means of an eccentric The steam is admitted a little before the extreme positions of the piston have been reached, also when the piston has been pushed forward a certain distance by the full force of the steam, the supply from the boiler is usually stopped, and the piston is impelled by the elastic force of the steam already in the cylinder The engine is then said to work expansively In some cases the steam is cut off at a half stroke, in some at one third, and in others at a smaller proportion of the entire stroke This is effected by making the foot of the slide valve of greater length When the steam is cut off at one third of the stroke, acting *expansively* for the remaining two thirds, the machine has only half the power it would have if the steam had access to the cylinder during the whole course, hence half the maximum force is obtained at the expense of one third of the steam

The supply of steam to the cylinder is regulated by the throttle valve, a circular metal plate fitting the steam pipe and moving on a horizontal axis The edges of the plate are bevelled, so that it is steam tight when closed The throttle valve is connected by a lever with the governor As the speed of the engine increases the balls of the governor fly outward, the lever is raised, and the valve partially closed

Steam engines may be divided into classes, according to several particulars, for example, engines may have cylinders fixed or oscillating, vertical or horizontal They may have a condensing apparatus, or no condensing apparatus We need only consider the third distinction, and divide engines into two classes—those in which the steam is condensed after leaving the cylinder, commonly called low pressure, and those in which the steam, after working the piston, passes to the atmosphere, called high pressure The exigencies of modern practice have tended to alter this distinction of low pressure and high pressure engines very materially In former times condensing engines always worked with low pressure steam, now, they frequently work with steam of high-pressure Hence the terms condensing and non-condensing more accurately define the two classes It is now usual to employ steam of a higher pressure than formerly, even with condensing engines The force of the steam from the moment the steam valve is closed is continually diminishing to the end of the stroke, and if it were cut off at a small fraction of the stroke, it might become so attenuated as not to drive up the piston On this account, when the expansive system is used, steam of higher pressure is employed The term high pressure, however, has been generally applied to engines in which the exhausted steam is driven into the air Such steam must evidently always exceed the pressure of the atmosphere

The non condensing engine is more simple, and consists of fewer parts than that which has been described It is generally used for locomotive engines, steam carriages, and steam vessels required to possess lightness and rapidity Although it is more elementary and simple than the other, it was not invented until many years after the condensing engine had been brought nearly to perfection In condensing engines the pressure of the steam in the boiler very frequently does not exceed from 4 to 6 lbs on the square inch, but in the present species, where there is no condenser, and the steam is allowed to pass into the open air, its pressure is seldom less than 20 lbs on the square inch In locomotive engines the pressure is usually from 50 to 60 lbs per square inch

The locomotive engine differs from the stationary engine in several important features Such engines require to be smaller and lighter than others, hence the apparatus for condensation is rejected, and high-pressure is used The boiler is an oblong cylinder, through which a number of tubes are arranged horizontally, in communication with the furnace and chimney By this means a very large surface is heated in contact with the water After moving the pistons, the steam escapes from the cylinders by two pipes meeting in a common tube or blast-pipe, which passes into the chimney When the expedient of turning the exhausted steam into the chimney was first adopted by George Stevenson, it was found that the speed of the locomotive on which the experiment was tried had been doubled

The working power of a steam engine is estimated in horse power, one horse power, as applied by engineers to the steam engine, being 33,000 foot pounds per minute

In order to calculate the effective power we require to know (1) the space through which the piston is moved per minute, (2) the size of the piston, (3) the mean effective pressure in the cylinder

The pressure in the cylinder is found by an instrument devised by Watt, termed an indicator It consists of a small cylinder 8 inches long and about 2 inches in diameter, communicating directly with the cylinder, and supplied with a piston When the pressure in the

cylinder varies, the piston of the indicator rises or falls A pencil attached to the indicator traces a curve on paper as the piston moves, from which the mean pressure of the steam can be calculated

As an example, let us find the horse power of an engine, the piston of which is 21 inches in diameter and makes 30 strokes per minute, the length of each being 50 inches, with a mean effective pressure of 10 lbs per square inch —

In one minute the piston moves through $50 \times 2 \times 30$ inches $= 250$ feet

The area of the piston $= \left(\frac{21}{2}\right)^2 \times \frac{22}{7} = 346\frac{1}{2}$ square inches.

Mean pressure on the whole piston $= 346\frac{1}{2} \times 10$ lbs

Therefore the number of foot pounds $= 3465 \times 250$

And the horse power $= 3465 \times 250 - 33000 = 26\ 25$

STEAM, LATENT HEAT OF See *Latent Heat*

STEARIC ACID A fatty acid occurring in most solid animal, and in some vegetable fats It crystallises in thin plates, at 69° C (156° F) it melts, and at a higher temperature distils with partial decomposition Formula $C_{18}H_{36}O_2$ With basis it forms salts called soaps, the neutral *stearate of soda* ($C_{18}H_{35}NaO_2$) is a component of ordinary washing soap

STEEL See *Iron*

STEELYARD A form of lever with unequal arms, in which the power is moveable so as to allow the arm to be increased or diminished at pleasure It is a lever of the first kind, in which the body weighed is close to the fulcrum In all cases the weight multiplied by its arm must be equal to the product of the power by its arm, the lever being purposely so constructed as to have its own centre of gravity at the fulcrum, in order that its weight may have no influence on the indications of the instrument Hence if on the one side the arm of the weight remains the same while the weight varies, and on the other the power remains the same while the arm varies, it follows that the variations of the power arm will be proportional to the variations of the weight The principle of the steel yard was applied in the *Roman statera*

STELLAR SPECTROSCOPE As the image of a star at the focus of the object glass of the telescope is a point, some modification is required to enable the spectroscope to give a good image of its spectrum This is effected by placing a cylindrical lens of short focus just within the focal point of the object-glass This draws the point of light into a line, and this line being received on the jaws of the slit, illuminates it throughout its whole length, the prisms being thus enabled to give a spectrum having appreciable breadth Dark or luminous lines can thus be detected (See *Spectroscope*)

ST ELMO'S FIRE A luminous phenomenon frequently observed and described both by ancients and moderns It is a ball of fire frequently seen in stormy weather on the rigging of ships, on the points of weapons, or the tops of the helmets of soldiers, even on the bare head or the tips of the fingers It is generally noiseless, but sometimes is accompanied by a roaring or hissing noise It is simply a brush or glow discharge of electricity on a large scale (See *Discharge*)

STEREOSCOPE (στερεος, solid, and σκοπεω, to view) An optical instrument devised by Sir C. Wheatstone for illustrating the phenomena of *Binocular vision* Two pictures are taken (at the present day photography is the sole agent employed) from slightly different points of view, so that one may represent the view as seen by the right eye, and the other the view seen by the left The stereoscope is an instrument for presenting these views, one to each eye, so as to produce the same optical effect as if the real scene were being viewed In the reflecting stereoscope a mirror is placed opposite each eye, and the pictures are so arranged that each is reflected by its own mirror into the eye for which it was taken In the refracting stereoscope the two pictures are mounted on a card, side by side, and are looked at through prismatic lenses which refract each picture apparently to the same place where they coalesce The reflecting stereoscope is the most perfect instrument, and is adapted for any sized picture, but the refracting instrument is the most popular (See *Binocular Vision*)

STORM See *Winds*

STORM GLASS Some amateur observers have great faith in the "chemical weather glass," as some instrument makers term it, as a correct indicator of meteorological changes, and they are likely to be confirmed in this view by the authority of the late Admiral Fitz Roy, who found it "useful for aiding, with the barometer and thermometer, in forecasting weather" "Again," he says, in his "Weather Book," "camphor glasses in proper positions and duly attended are most useful to a quick eye and skilled perception," page 232 There are many other passages in the same work descriptive of its indications

The following is a common recipe for making a storm glass. Take $2\frac{1}{2}$ drachms of camphor,

38 grains of nitre, and 38 grains of sal-ammoniac, dissolve in 9 drachms of water and 11 drachms of rectified spirit with a gentle heat Put the mixture into a long glass tube and close it with a brass cap with a small hole in it to admit air Other accounts say the tube is to be hermetically sealed

The instrument maker generally gives a paper containing the supposed weather indications of this scientific toy It is not necessary to repeat them here, since Mr Tomlinson has shown conclusively (Phil Mag, August 1863) that neither electricity, nor light, neither wind nor cloud, have any action on the mixture, but that changes in temperature are alone concerned in bringing about its varied effects "The storm glass acts as a rude kind of thermoscope inferior, for most purposes of observation, to the thermometer It does not seem to be capable of reference to a standard, and hence observations made with it scarcely admit of being registered, although attempts at a scale are made by some instrument makers If, however, two or more of such graduated instruments be placed in and about a house, their indications will vary considerably, according as they are more or less exposed to the action of radiation, and it is difficult to see how the glass can be protected from radiation except by enclosing it in another glass, and under such circumstances its action will be very feeble" "Two tubes containing the same mixture were placed, one in the window, and the other in a test-glass within a foot of the window, the first acted well, the second did not act at all, on account of its cooling being interfered with by the shelter of the test glass, but on taking it out of the glass and placing it on the window-pane, it began to act in a few hours, and has behaved well for many weeks"

STORMS, LAW OF See *Winds*

STORM WARNING A signal indicating the anticipated approach of stormy weather Although in extra-tropical latitudes it is difficult to form certain deductions as to approaching storms, yet certain general laws have been detected which enable meteorologists to predict the course of storms actually in progress, and, in some instances, to announce the approach of a storm A large proportion of the storms which visit Europe come from the west and south-west, and therefore telegraphic communications from suitable westerly stations may serve to prepare more easterly stations for the approach of a storm which is actually in progress at the former In like manner, the interchange of telegraphic communications respecting the barometric pressure at different stations may serve to indicate such disturbances of atmospheric equilibrium as are not likely to pass away without stormy weather

The list of storm warnings issued under the direction of the Meteorological department of the Board of Trade, not only to English ports but to the continent, exhibits so small a proportion of failures (considering all the circumstances of the case) as to encourage a belief that time and experience only are wanting to render complete the system on which predictions are founded

STREAM TIN. See *Tin*

STRONTIUM The metallic basis of strontia, one of the alkaline earths, it was separated in the metallic state by Sir H Davy in 1808, it possesses a yellow colour, but is not so dark as gold Specific gravity 2 54 Atomic weight 87 5 Symbol Sr The most important compound of strontium is the oxide,—*Strontia* (SrO) This is a greyish white porous mass Specific gravity 3 9 When water is poured upon it, combination takes place, and it becomes very hot and crumbles to a white powder of the *hydrate of strontium* ($SrO\ H_2O$) This hydrate is similar in its properties to the corresponding barium and calcium hydrates. It dissolves in water, forming a strongly alkaline solution, which absorbs carbonic acid readily, becoming coated with a crust of insoluble carbonate When a hot, saturated solution of strontia is allowed to cool, it deposits the hydrate in needle shaped crystals Compounds of strontium communicate a red colour to flame, and when examined in the spectroscope give a spectrum containing characteristic red and blue lines

STRENGTH OF MATERIALS The power of the solid materials, of which structures are composed to resist forces tending to bend or break them The conditions which determine the strength of solid bodies, and their power to resist forces tending to produce fracture, are found by experiment A force acting on a solid body may tend to separate its parts in different ways The force may be—

1 A direct pull, tending to produce extension, or, (when rupture results), to produce a tearing fracture
2 A direct pressure, tending to produce compression, or a crushing fracture
3 A force tending to produce distortion, or a shearing fracture
4 A twisting or wrenching force
5 A bending force, which tends to break the body across

To determine fully the strength of a solid, it will be necessary to find, in connection with each

kind of strain, the ultimate or *breaking* load, the *proof* load, or that which will just be borne without impairing the strength of the material, and the safe or *working* load Most structures would be broken in time by a load which would not produce fracture at once, on this account, and to provide for unforeseen contingencies, the working load on each piece of structure is made less than the proof load, in a certain ratio determined by practical experience The practice of engineers is by no means uniform

Experiments to test a piece of material are conducted in two ways If the solid body is to be afterwards used, the experiments must be so made as to avoid impairing the strength, if the body is to be sacrificed for the sake of ascertaining the strength of the material, the load is to be increased by degrees until fracture is produced To determine the proof strength much time and care is required The load must be repeatedly applied and removed, and its effect in altering the figure of the material observed after removal If the alteration does not sensibly increase by repeated applications, the load is within the limit of proof strength By gradually increasing the forces applied, two loads will at last be found, one of which is under, and the other beyond, the proof strength Mr Fairbairn has made a series of experiments on the proof strength of wrought iron girders, and has found that, when the load applied was one fourth of the breaking weight, the beam withstood 596,790 successive applications of it without perceptible alteration, when the load was two sevenths of the breaking load, and applied 403,210 times, the beam showed a slight increase of permanent set, when two fifths of the breaking load was applied the girder broke after the 5175th trial

It was formerly supposed that the production of a set or change of figure, which continues after the removal of the load, was a sign that the proof strength had been exceeded, but Mr Hodgkinson showed that this was not the case, inasmuch as any load, however small, produces a set in almost all materials The strength of wrought iron, to resist stretching and tearing, is greater than the power to resist crushing The strength is measured by the area of a cross section multiplied by the *factor of strength*, determined by experiment Good wrought iron will resist a tension of 22 tons per square inch, and a crushing force of 16 tons, but cast iron will not resist a tension of more than $7\frac{1}{2}$ tons, while the crushing strength exceeds 40 tons per square inch of section According to Mr Hodgkinson's experiments the resistance of cast iron to crushing is more than *six* times its tenacity Homogeneous iron and steel are twice as strong as common wrought iron Experiments made at Mr Kirkcaldy's testing works in 1866, showed that a bar of Howell's homogeneous iron required 44 6 tons to tear it, but the power to resist compression was not proportional to the tenacity

Among different specimens of dry wood of the same kind, the densest are the strongest The stretching strength in the direction of the grain is greater in those kinds of wood which have the fibres longest, and most distinctly marked The tenacity across the grain is always much less than that along the grain The resistance to crushing in dry timber ranges from one-half to two thirds of the tenacity, and is twice as great for dry timber as for green timber The tendency to cross-breaking is somewhat more than the tendency to tearing

STRYCHNINE A vegetable alkaloid extracted from *Nux Vomica*, and St Ignatius' beans, &c It crystallises in white prisms which are permanent in the air Its composition is $C_{21}H_{22}N_2O_2$ It has an intensely bitter taste, and is extremely poisonous It is very slightly soluble in water Strychnine is a powerful base, and unites with acids forming well crystallised salts

SUBLIMATION A kind of distillation when the substance submitted to heat rises in vapour, and condenses not as a liquid, but as a solid, either crystalline or pulverulent The product is called a *sublimate*, thus sulphur forms a sublimate known as flowers of sulphur Perchloride of mercury, iodine, &c, forms crystalline sublimates The former of these is called corrosive sublimate

SUBMAGNET An unusual name for the keeper of a magnet (See *Keeper*)

SUBMARINE TELEGRAPHY See *Cable, Submarine*, and *Telegraph*

SUBMERSION FIGURES OF LIQUIDS Under *Cohesion Figures of Liquids* will be found a notice of the figures produced, when a drop of a liquid, such as oil of lavender, is gently deposited on the surface of a liquid such as water In such cases the drop so deposited must either be less, or must not greatly exceed in specific gravity, the surface on which it is deposited When the drops are much heavier than the liquid on which they are deposited, and this liquid has considerable depth, as when contained in a cylindrical glass, the drop sinks below the surface and forms beautiful, striking, and complicated figures, as when a drop of fousil oil diffuses in a column of paraffin, oil of lavender in spirit of wine, croton oil in benzol or in paraffin, cochineal in alum water, benzol in ether, bitter almonds in benzol Descriptions and drawings of these and other figures are given by Mr. Tomlinson in the Phil Mag for June and November 1864.

SUCCINIC ACID (*Succinum*, amber) A volatile acid first obtained from amber, but generally prepared by the fermentation of malic acid It crystallises in prisms which are permanent in the air, tolerably soluble in water, less so in alcohol, and almost insoluble in ether Formula, $C_4H_6O_4$ Melting point, 180° C Boiling point, 235° C It unites with bases, forming a well defined series of salts

SUCROSE Another name for cane sugar (See *Sugar*)

SUCTION PUMP To raise water from a depth, if not exceeding about twenty five feet, the suction or "house" pump is often employed Its action depends upon the atmospheric pressure, and is based upon the fact (see *Barometer*) that the pressure of the air will support a column of water about 33 feet in height The suction pump consists of a cylinder open at the top into which a piston fits, provided with a valve opening upwards The bottom of the cylinder is pierced by a tube which reaches down to the water which has to be raised Where this tube enters the cylinder, there is a valve opening upwards The piston is worked up and down by any convenient lever handle To start the pump it is necessary that the valves should be nearly perfectly air tight, so that, after a pump has been out of use for some time, it is necessary that the valves, which are usually made of leather, should be wetted When now the piston is raised, the elasticity of the air in the cylinder and tube beneath is diminished, consequently the air, pressing upon the water in the well, will force the latter up the tube Where the piston descends the lower valve closes by its weight, and the air between it and the piston is forced through the valve of the latter This goes on until, by successive strokes, the water is brought into the cylinder Then, when the piston descends, the water in the cylinder closes the lower valve, and is forced through the piston's valve, and consequently lifted when the piston is lifted It escapes through an opening in the top of the cylinder, or of a pipe in continuation thereof If the valves, &c, were perfect, it would be possible to raise water by means of the suction pump to the height of the water barometrical column (say 33 feet) at which height the weight of the water would keep the atmospheric pressure in equilibrium Practically such pumps are useless for depths exceeding 20 to 25 feet

SUGAR This term is applied to several carbohydrates of vegetable origin which have many properties in common They are soluble in water, in general crystallisable, have a sweet taste, are neutral to test paper, and their solutions rotate the plane of polarisation of a ray of light (See *Saccharometer*) The substance to which this name is generally applied is *cane-sugar* or sucrose ($C_{12}H_{22}O_{11}$), extracted from cane juice, beet juice, &c It rotates the plane of polarisation to the right Amongst other sugars are dextrose or *grape sugar* ($C_6H_{12}O_6$), *lævulose*, which is one of the constituents of fruit sugar or inverted sugar Under the influence of dilute acids, or long boiling with water, cane sugar is converted into what is called inverted sugar, a mixture of dextrose and lævulose It is called inverted, because the left handed rotation of the lævulose is greater than the right handed rotation of the dextrose Under the influence of ferments sugar is converted into alcohol and carbonic acid Sugar forms several crystalline compounds with lime

SUGAR OF LEAD See *Acetates, Acetate of Lead*

SULAPHAT (Arabic) The star γ of the constellation Lyra

SULPHATES Combinations of sulphuric acid and bases are called sulphates The most important are the following —

Sulphate of Aluminium (Al_2O_3 $3SO_3$) This is prepared in an impure state on the large scale, and sold as concentrated alum It forms a crystalline solid mass, which has a taste somewhat resembling alum, and is readily soluble in water It forms double salts with other sulphates, which are known under the general name of alums Of these the potassio-aluminic sulphate, or potash alum, and the ammonio aluminic sulphate, or ammonia alum, are of importance (See *Alum*)

Sulphate of Barium ($BaSO_4$) occurs native as the mineral *heavy spar*, sometimes crystalline, sometimes massive It is prepared artificially by adding a soluble sulphate to a soluble barium salt It is a heavy, white, amorphous powder, insoluble in water and acids Specific gravity, 4 5 It is used as a pigment

Sulphate of Calcium ($CaSO_4$ anhydrous, and $CaSO_4$ $2H_2O$ hydrated) The anhydrous salt occurs native as *anhydrite*, and is largely used in commerce under the name of *gypsum*, or *Plaster of Paris* It is a white powder almost insoluble in water When mixed with a small quantity of water, so as to form a thin paste, it gradually thickens, and, in the course of a few minutes, solidifies to a hard mass of hydrated sulphate by absorption of water Owing to this property it is of great use in taking casts and moulds of objects The hydrated sulphate of calcium is met with in nature under the name of *selenite* and *alabaster*

Sulphates of Chromium These are unimportant by themselves, but they form double salts with other sulphates, which are known under the name of *chrome alum*. (See *Alum*)

Sulphate of Copper ($CuSO_4\ 5H_2O$), called also blue vitriol and copper vitriol This is of a beautiful blue colour It crystallises in large oblique prisms, which effloresce slightly in the air When heated to 200° C (392° F), the water of crystallisation is driven off, and the white anhydrous sulphate is left This has a very powerful affinity for water, a trace of moisture restoring the blue colour On this account it is sometimes used for detecting the presence of water in alcohol and other liquids, or for dehydrating them Sulphate of copper dissolves readily in water, but is insoluble in alcohol and ether It is largely used in commerce It unites with ammonia, forming a compound $CuSO_4\ 4NH_3\ H_2O$, which is precipitated in crystals, when alcohol is added to the rich blue solution formed when ammonia in excess is added to sulphate of copper

Sulphate of Iron, known also as *green vitriol* or *copperas* ($FeSO_4\ 7H_2O$), occurs in well-defined prismatic crystals, of a pale green colour, readily soluble in water Both the crystals and solution gradually absorb oxygen from the air, with formation of a reddish-yellow basic sulphate It is largely used in dyeing, in the manufacture of ink, Prussian blue, &c, and, owing to its ready absorption of oxygen, it is employed in the laboratory as a reducing agent

Sulphate of Lead ($PbSO_4$) This is met with in nature as the mineral *Anglesite* It is prepared artificially by adding a soluble sulphate to a soluble lead salt It is a heavy white powder, insoluble in water, but slightly so in dilute acids

Sulphate of Magnesium or *Epsom Salts* ($MgSO_4\ 7H_2O$), occurs native as the mineral *Epsomite* It crystallises in four sided needle-shaped prisms, which are permanent in the air, and are very soluble in water, but difficultly so in alcohol Their taste is bitter and nauseous

Sulphate of Manganese ($MnSO_4$) forms very small crystals, of a faint red tinge, very soluble in water

Sulphates of Mercury, Mercuric Sulphate ($HgSO_4$) forms colourless prismatic crystals, which are decomposed by water into an acid and a basic salt The basic salt is a lemon yellow powder slightly soluble in water It was formerly called *turbith mineral* Its formula is $3HgO\ SO_3$, The *mercurous sulphate* (Hg_2SO_4) is a white crystalline powder, very slightly soluble in water

Sulphate of Nickel ($NiSO_4\ 6H_2O$) crystallises in emerald green octahedra, which dissolve readily in water, and effloresce to a white powder in the air

Sulphate of Cobalt ($CoSO_4\ 7H_2O$) forms red prismatic crystals, which are tolerably soluble in water, and effloresce in the air, forming a rose coloured powder

Sulphates of Potassium The neutral sulphate (K_2SO_4) crystallises in four sided, colourless, hard prisms, slightly soluble in water When heated, they decrepitate violently, and, at a full red heat, melt

Bisulphate of Potassium ($KHSO_4$) crystallises from its solution in octahedra, which melt at 197° C (387° F), solidifying to a white crystalline mass It is very soluble in water, but is decomposed by a large quantity

Sulphate of Sodium (Na_2SO_4), or Glauber's salt, is prepared in enormous quantities in the manufacture of carbonate of soda, and in other chemical manufactures In the crystalline state it forms large colourless prisms, which contain ten atoms of water It has a bitter cooling taste, and dissolves readily in water Its solutions exhibit in a high degree the phenomena of supersaturation The crystals effloresce in the air, and below the boiling-point of water become anhydrous

Sulphate of Strontium ($SrSO_4$) This is met with native as the mineral *celestin* It is prepared artificially by adding any soluble sulphate to a soluble strontium salt It is a heavy white powder, almost insoluble in water, but sufficiently so to form a precipitate when its solution is added to a barium salt

Sulphate of Zinc ($ZnSO_4\ 7H_2O$), known also as *white vitriol*, or zinc vitriol, crystallises in right rhombic prisms, which are easily soluble in water. It is used in medicine, and also in certain manufactures

SULPH-INDIGOTIC ACID Indigo dissolves in fuming sulphuric acid, forming a conjugate sulpho-acid of the formula $C_8H_5NO\ SO_3$, which is soluble in water and capable of forming salts, which are, however, not very definite or crystallisable The acid is used in the laboratory as a reagent and the potassium salt is used in dyeing, it is a copper-coloured deliquescent mass soluble in water, and forming an intensely blue solution

SULPHITES Combinations of sulphurous acid with bases are called sulphites The following are the most important

Sulphite of Ammonium ($(NH_4)_2SO_3\ H_2O$) is a white crystalline salt having an alkaline reaction

Sulphite of Calcium ($CaSO_3\ 2H_2O$), crystallises in six-sided prisms, and is difficultly soluble in water It is sometimes used as an antiseptic

Sulphites of Potassium The neutral salt ($K_2SO_3\ 2H_2O$) is a deliquescent crystalline salt

The acid sulphite ($K_2SO_3 SO_2$) forms hard granular crystals which are soluble in water and are permanent in the air This salt is of frequent use in laboratories as a reducing agent, and as a convenient source of sulphurous acid, which is evolved from it in the gaseous state on the addition of a mineral acid

SULPHO ACIDS When strong sulphuric acid is added to many organic compounds, it unites with them, forming conjugate acids, which are known generally as sulpho acids, and specially by the name of the compound with the prefix sulpho, thus we have sulpho benzoic acid, sulpho succinic acid, &c

SULPHO CYANIDES Compounds of sulpho cyanic acid (CNHS) with bases, or sulpho-cyanogen (CNS) with metals, are called sulpho-cyanides The only ones of importance are the following —

Sulpho cyanide of Potassium (KCNS) crystallises in long needle-shaped prisms, which are deliquescent, easily fusible, and very soluble in water and alcohol

Sulpho cyanide of Ammonium ($(NH_4)CNS$), crystallises in large colourless plates which are very soluble in water When this salt in the powdered state is suddenly stirred up with its own weight of hot water, so great a reduction of temperature takes place that the solution is lowered to the freezing point These two salts have been proposed for use in photography owing to their property of dissolving chloride of silver

Sulpho-cyanide of Iron When a sulpho cyanide is added to a per salt of iron an intense blood red solution is formed This is a very delicate test for iron, and is of frequent employment in the laboratory It is scarcely known in the solid state

SULPHUR A non-metallic element known to the ancients When pure it is a brittle lemon yellow solid Specific gravity 2 05 Atomic weight 32 Symbol S It melts at 120° C (248° F) forming a pale yellow liquid, and at 440° C, it boils, between these temperatures it gets dark and viscid, until at about 220° C (428° F) it has the consistency of thick treacle, above this temperature it gets thinner again It assumes many allotropic conditions, of which the most remarkable are the following —

Common Sulphur crystallises readily in octahedrons, and dissolves easily in disulphide of carbon

Prismatic Sulphur is of a yellowish brown colour Specific gravity 1 98 It dissolves readily in disulphide of carbon.

Amorphous Soluble Sulphur is the form in which sulphur is precipitated from its solutions by acids or by the sudden condensation of its vapour It is readily converted into the normal octahedral variety

Amorphous Insoluble Sulphur is a soft magma, obtained when disulphide of chlorine is decomposed with water, it is insoluble in disulphide of carbon

Plastic Insoluble Sulphur is obtained by heating melted sulphur to a temperature of about 270° C (518° F), and then pouring it into cold water In this state it is a soft, yellowish-brown elastic mass which can be kneaded between the fingers and moulded into any form, it gradually becomes converted into ordinary sulphur on standing

The oxygen compounds of sulphur are numerous The most important of these are the following

Oxides of Sulphur Sulphur unites with oxygen in many proportions forming acids, of these we need only mention the following —

Sulphurous Acid, sulphurous oxide, or dioxide of sulphur (SO_2), is formed when sulphur is burnt in the air or in oxygen gas It is a colourless heavy gas of a peculiar suffocating odour, more than twice as heavy as atmospheric air, and very soluble in water When cooled in a powerful freezing mixture or condensed under a pressure of three atmospheres, sulphurous acid liquefies to a colourless mobile liquid of specific gravity 1 45, under the ordinary atmospheric pressure this boils at $-10°$ C (14° F) When cooled to $-79°$ C, it solidifies to a white crystalline mass Sulphurous acid has a considerable tendency to absorb oxygen, forming sulphuric acid It is largely used as a bleaching agent and as a disinfectant Sulphurous acid unites with bases, forming a well-defined series of salts which are known as sulphites, which see

Sulphuric Acid Anhydrous sulphuric acid (SO_3) or, as it is sometimes called, sulphuric anhydride, forms beautiful white needles like asbestos Its affinity for water is very great, and when dropped into it it hisses like a red hot iron Its combination with water is called *Sulphuric Acid* or *Oil of Vitriol* ($SO_3 H_2O$), which is an oily colourless liquid, boiling at 327° C (620 5° F), possessing a specific gravity of 1 84, it has a very powerful affinity for water, and when exposed to the air absorbs moisture rapidly On this account it is of great value in the laboratory as a desiccating agent for gases When mixed suddenly with water, the temperature rises greatly, sometimes as much as 100° C Its affinity for water is so great that it takes it from organic substances, such as wood, sugar, &c, in which it is supposed not to exist ready formed but only in its elements. Under the powerful influence of the acid these unite and are withdrawn,

liberating the carbon. A drop of strong sulphuric acid left for a few minutes on almost any organic compound carbonises it, leaving a charred stain. Oil of vitriol dissolves the anhydrous acid, forming what is known as fuming sulphuric acid. On the large scale sulphuric acid is prepared in enormous quantities by a process somewhat as follows. Sulphur or iron pyrites (sulphide of iron) is burnt in properly constructed furnaces, and the resulting sulphurous acid together with nitrogen and excess of air are carried into a large chamber made of lead, having a capacity of sometimes 100,000 cubic feet. On its passage there, the sulphurous acid takes up nitric peroxide (NO_2) and inside the lead chamber steam is admitted. A reaction here takes place between the sulphurous acid and the nitric peroxide by which the latter is reduced to nitric oxide (NO), and the sulphurous acid is oxidised to sulphuric acid and unites with the aqueous vapour. The reaction may be expressed by the following equation, $NO_2 + SO_2 + H_2O = H_2SO_4 + NO$. As soon as the nitric oxide is formed it absorbs oxygen from the air which is present, and becomes again converted into nitric peroxide, which immediately passes the additional atom of oxygen to another portion of sulphurous acid, and so on, a small portion of nitric peroxide thus oxidising an indefinite quantity of sulphurous acid, as it acts merely as a carrier of oxygen. The liquid which condenses on the floor of the lead chamber is then drawn off, and concentrated by evaporation until it attains the specific gravity of 1.7, this is then transferred to glass or platinum retorts and boiled down until it attains the specific gravity of 1.84, when it becomes what is known in commerce as oil of vitriol. Sulphuric acid is the strongest known acid at ordinary temperatures, and it unites with all bases forming salts which are called sulphates. When added to salts of other acids it displaces them, taking possession of the base, except in the case of some perfectly insoluble compounds, such as certain silicates. At a high temperature, however, some other acids, such as silicic and boracic acids, appear stronger than sulphuric, as, owing to their diminished volatility, they remain fixed at temperatures at which sulphuric acid cannot exist uncombined. For a description of the most important compounds of this acid, see *Sulphates*.

There are several other sulphur acids, which are, however, unimportant. Their names and formulæ are *hypo-sulphurous acid*, $H_2S_2O_3$, also called thio sulphuric, or dithionous, or sulphuretted sulphurous acid. Dithionic or *hypo sulphuric acid* $H_2S_2O_6$. Trithionic or *sulphuretted hypo-sulphuric acid*, $H_2S_3O_6$. Tetrathionic acid, $H_2S_4O_6$, and Pentathionic acid $H_2S_5O_6$. These all form salts, only one of which (*Hyposulphite of Sodium*, which see), is of any importance.

Sulphides, combinations of sulphur with other elements, especially the metals, are called sulphides. Those of special importance are described under the different metals. Some metallic sulphides appear to act as acids, whilst others act as bases, and these can unite with each other, forming definite and sometimes well crystallised compounds, which are called sulphur acids. These are analogous to the oxygen salts, the sulphur merely replacing oxygen.

Sulphur unites with chlorine in several proportions, the *disulphide of Chlorine* (Cl_2S_2) sometimes called protochloride of sulphur, is the most important. It is formed when chlorine gas is passed over sulphur and the product rectified. When pure it is a reddish yellow liquid, fuming strongly in the air and having a disagreeable penetrating odour, it boils at 136° C (277° F), its specific gravity is 1.68. This compound is largely used in the manufacture of vulcanized india rubber.

SULPHUR, ACTION OF LIGHT ON. According to M. Lallemand, sulphur is converted into an amorphous variety by the direct action of sunlight, inasmuch as sulphur, previously soluble in sulphide of carbon and crystallisable, is converted into an amorphous modification, insoluble in sulphide of carbon. A concentrated solution of sulphur in sulphide of carbon is placed in a sealed tube, and the tube is exposed for some time to the action of the sun's rays, concentrated by a lens, this causes a copious precipitation of sulphur as an amorphous insoluble powder.

SULPHURIC ACID. See *Sulphur*.

SULPHUROUS ACID. See *Sulphur*.

SULPHUR, SPECTRUM OF. In a Geissler's tube, sulphur, when warmed and rendered incandescent by the passage of an induction current, gives rise to a spectrum of bright bands of Plucker's *first order*, when strongly heated the bright bands give place to bright lines, the spectrum changing to one of Plucker's *second order*.

SUMMER. See *Seasons*.

SUMMER CLIMATES. See *Isotherals*, *Isothermal*, *Climate*, &c.

SUN. (Derivation uncertain.) The central and controlling orb of the planetary system, the source of light and heat to this earth and all the other globes which form that system.

The sun has a diameter of 852,900 miles. He is either perfectly spherical in shape, or so nearly so that no instruments we can use could exhibit any difference which may exist between his polar and equatorial diameters. The opinion of astronomers on this point is not founded on the mere measurement of the solar disc, but on a comparison of all the observa-

tions made upon the sun at Greenwich and other leading observatories, insomuch that, as was well remarked by the Astronomer Royal, any measurements exhibiting a difference between the sun's polar and equatorial diameters would simply establish their own inexactness. The volume of the sun exceeds that of the earth no less than 1,252,691 times. His mean density is almost exactly one-fourth of the earth's, so that his mass exceeds the earth's 315,000 times. He outweighs all the planets together about 750 times. Gravity at his surface exceeds gravity at the earth's 27·1 times, so that a terrestrial pound would weigh nearly a quarter of a hundredweight if removed to the sun's surface, and bodies let fall from a height of 436 feet would reach the sun's surface in one second, and have acquired in that time a velocity of 872 feet per second—that is, of about ten miles per minute.

The sun rotates upon an axis inclined 7° 20′ to the plane of the ecliptic, but considerably less to the mean plane of the planetary motions. Owing to the inclined position of his axis, his equator is sometimes presented to the earth as a straight line, at others somewhat bowed northwards or southwards. The curvature is very small, even at its maximum. On about the 9th of December and the 7th of June the sun's equator is seen as a straight line inclined 7° 20′ to the ecliptic, the eastern extremity being north of the ecliptic at the former date, and south of the ecliptic at the latter. On or about September 11th, the solar equator exhibits its greatest curvature, its convexity being southwards, and the general direction of the solar equator coinciding at this time with the ecliptic. A similar appearance is presented on or about March 10, but the convexity is now turned northwards.

The rotation of the sun, as determined by the motion of the solar spots, would appear to vary according to the solar latitude, though, of course, in reality there can be but one rotation period, and the differences actually observed are due to the proper motion of the solar spots. We owe to the labours of Carrington the discovery of this interesting relation. He assigns the following formula for the movement of a spot in 24h. of mean solar time in solar latitude l:—

$$865' - 165' \sin^{\frac{7}{4}} l$$

Thus the time of a complete revolution of a point on the sun's equator, as viewed from the earth, would be almost exactly 25 days, but, considered with reference to the celestial sphere, a complete revolution of such a point takes place in about 24·2 days. Sir John Herschel adds to this that the complete revolution of a spot in solar latitude 15° takes place in 25·44d., and that of a spot in latitude 30° takes place in 26·24d. These variations serve to account for the discrepancies in the observations made by Scheiner, Bianchi, Laugier, Delambre, and others.

The Solar Spots. Soon after the invention of the telescope it was discovered, independently, by Galileo, Fabricius, and Fr. Scheiner, that the disc of the sun is marked by spots or *maculæ*. These objects were explained in different ways by the astronomers of those days. Some supposed that they are planets of great size travelling close to the sun, and a name was actually given to these imaginary bodies; they were called the Borbonian stars, in honour of the royal family of France. Galileo, and afterwards Hevelius, suggested that the spots may be due to the presence of scum, or *scoriæ*, upon the surface of solar seas. La Hire thought that there are dark bodies beneath the solar oceans, and that, when these are carried near the surface, we see them through the semi-transparent liquid. We owe to Dr Wilson, of Glasgow, the recognition of certain peculiarities of appearance presented by some at least of the solar spots, which would seem to indicate that they are cavities or depressions beneath the general level of the sun's surface. He noticed that a large spot, which was visible during the latter part of the year 1769, changed in appearance as it approached the edge of the solar disc in a manner which was not consistent with the view that the spot was a mere surface stain. The dusky penumbra which surrounded the dark umbra of the spot should have been narrower on the side towards the edge of the disc, but, instead of this, that part of the penumbra was markedly the wider. It appeared to Wilson that this peculiarity was best explained by the theory that a spot is a cavity with shelving sides and a level bottom, and that, when a spot approaches the edge of the solar disc, the line of sight directed towards the further side of the spot meets the sloping side of the cavity more squarely, so that that side appears widest. These views were confirmed by the researches of Sir William Herschel in 1777. Observing the same general appearances which had been noticed by Dr Wilson, he was led to explain them by a theory according to which the material in which a spot-cavity is formed is neither gaseous nor liquid. He argued that the long continuance of the spots, and still more the relative permanence of the faculous ridges around a large spot, show that the matter in which these peculiarities present themselves has not the mobility which we associate with gaseous and liquid substances. He therefore suggested that the sun is surrounded by two strata of clouds, suspended in a transparent atmosphere at different elevations. The upper stratum he supposed to be self luminous, and to be

the true source of the solar light (or the *photosphere*, to use the convenient term adopted by Schroter) The lower stratum he regarded as opaque, and only rendered luminous by the light which falls upon it from the upper stratum When an aperture is formed in the outer stratum we see merely a penumbral spot, because the lower stratum is revealed, and this stratum, though less luminous than the outer, is yet capable of reflecting a large amount of light When an opening is formed through both layers, the upper stratum being removed over a larger area, we see a penumbral fringe, formed by the lower stratum, and through the smaller opening in this stratum we see the dark body of the sun Where the opening in the upper stratum is no larger or less than the opening in the lower, the spot will exhibit no penumbra, but be uniformly dark all over its extent

The progress of recent researches by no means favours the supposition that the body of the sun is dark, as Sir W Herschel supposed On the contrary, it seems certain that throughout the whole globe of the sun the most intense heat prevails, and that even though portions of that globe may be solid or liquid, they owe the existence of those conditions, not to relative lowness of temperature but to the enormous pressure to which those portions are subjected

Among the more modern views respecting the nature of the solar spots, those which have been expressed by M Faye on the one part, and by the astronomers of the Kew Observatory on the other, deserve special mention, as indicating the direction in which modern science is looking for an explanation of these perplexing appearances

According to M Faye the sun's interior is gaseous, intensely hot, but of low radiating power, while the photosphere is at a lower temperature, but possesses a high radiating power Thus, if the outer photosphere be thrust aside by an up-rush of vapour, we see a dark spot, because the light received from the interior is relatively small According to Messrs De La Rue, Stewart, and Loewy, the appearance of a spot is due to a diminution of temperature caused by a down rush of cooling vapour

Between these two theories it seems not difficult to decide, though doubts will still remain whether either one or the other supplies the true interpretation of spot phenomena M Faye's theory seems completely disposed of by Balfour Stewart's theory of exchanges, according to which it should follow that were the interior of the sun really constituted as M Faye supposes, we ought still to receive as much light where the photosphere is broken open, since the photosphere on the farther side of the sun would send us its light, and whatever proportion of light the gaseous interior was capable of absorbing it would in turn supply

But there can be no doubt that the problem is one peculiarly susceptible of treatment by spectroscopic analysis In 1866, Mr Lockyer made some observations which seem to bear most importantly on the subject He found that the absorption bands belonging to the solar spectrum were not only visible in the spectrum belonging to the light from a sun spot, but were apparently increased in thickness These observations have since been confirmed by Mr Huggins It would seem to follow, as a legitimate conclusion from them that the spots are really caused in some such way as Messrs De La Rue and Stewart have suggested as the best interpretation of their long series of solar observations The whole subject still remains full of perplexity, however, though it may well be hoped that the researches of the next few years will serve to throw much light upon the problem

A few words may be added respecting the general appearance and changes of appearance of the solar spots The observation made by Dr Wilson, though doubtless true of the particular spot he watched, and also confirmed by observations made in modern times, yet is not to be regarded as indicating a peculiarity always observable On the contrary, several eminent solar observers, and amongst others the Rev Mr Howlett, (whose persistent observation of sun-spots merits all praise), have noticed that many sun spots approach the edge of the solar disc without exhibiting any of those characteristics which led Dr Wilson to regard sun spots as cavities with shelving sides

Some spots have been observed to change very rapidly in form, in particular, shortly before disappearing But large spots have remained visible for a considerable time In 1779 a spot remained visible for half a year Schwabe has even seen a group of spots pass eighteen times across the sun's disc before disappearing, a fact which would indicate a continuance of more than fifteen months

At certain seasons spots are more numerous than at others Schwabe was led to study this peculiarity, and was rewarded by the interesting discovery that the spots increase and diminish in frequency within a period of about $10\frac{1}{3}$ years (Wolf has since shown that the more exact value of the period is $11\frac{1}{9}$ years) And it has been further discovered through the researches of Lamont, Sabine, Wolf, and others, that this period corresponds with the periodic variation of the diurnal declination changes of the magnetic compass

The Faculæ.—These are bright streaks commonly seen in the neighbourhood of spots which

are approaching the sun's limb. Secchi says that though they appear bright in this position they are not in reality brighter than the centre of the sun. The same eminent solar observer believes them to be immense waves of matter indicating the disturbance to which the formation of a spot is due. Messrs De La Rue, Stewart, and Loewy, consider the faculæ as probably consisting of solid or liquid bodies slowly subsiding in a gaseous medium. From their falling behind the spots it is inferred that they were originally lifted above the general level and in the process fell behind because coming into regions of more rapid rotation.

The Granules. The sun's surface, when carefully studied under high powers, is found to exhibit a granulated texture. Different observers use different modes of illustrating this texture. Least exact of all, perhaps, is the illustration according to which the sun's surface is represented as covered with masses resembling willow leaves in form. All the best observers, Dawes, Huggins, Lockyer, Secchi, &c., concur in regarding the general shape of the granules as irregular, and not commonly elongated except in the neighbourhood of the spots.

SUN, DISTANCE OF THE. The determination of the sun's distance may be regarded as the fundamental problem of practical astronomy, since on the solution of this problem depend all our estimates of scale, either as respects the solar system or the stellar distances.

The methods which have been used for determining the sun's distance are—1. Observations of the transits of Venus, (see *Venus*); 2 and 3. Observations of the parallax of Mars, according to two different methods, (see *Mars*); 4. The comparison of the velocity of light as measured by terrestrial experiments, and as determined by observations made on Jupiter's satellites, (see *Jupiter*); 5. Observations of the amount of the *moon's parallactic inequality*, (see *Lunar Theory*); and, 6thly. Observations of the effect on the sun's apparent motion of the earth's revolution round the common centre of gravity of the earth and moon. These methods have given results which may be thus tabulated (though it is to be noticed that the same method, or even the same series of observations, will give slightly different results, according to the method of calculation employed)—

	Solar Parallax
Method 1, transit of Venus in 1769, Encke's estimate,	8.578″
Methods 2 and 3, Winnecke's estimate,	8.964
,, ,, Stone's estimate,	8.930
Method 4, Foucault's estimate,	8.960
Method 5, Hansen's estimate,	8.916
Method 6, Leverrier's estimate,	8.950

It will be seen that the sun's equatorial horizontal parallax (see *Parallax*), as determined by the first method, seems to fall considerably short of the other estimates. Mr Stone has shown, however, that the error has arisen from an inexact mode of treating the observations made in 1769. By a more satisfactory process he obtains the result 8.91″. It will be noticed also that he has obtained an independent result 8.93″. He has further detected a mistake in Leverrier's estimate, arising from an error in computation, and thus reduces the parallax by the sixth method to 8.89″.

Combining all the best modern results, it would seem as though the value 8.9″ fairly represented the sun's parallax. But in the table of *elements* 8.94″ is the assumed value, in accordance with a suggestion made by Leverrier and Airy. The mean distance of the sun, on the assumption that the parallax is 8.94″, is 91,430,000 miles.

SUPERIOR PLANETS. Those planets whose orbits lie outside the earth's.

SUPERSATURATION. Referring to *solution* for a definition of *saturation*, a liquid is said to be *supersaturated*, when being saturated at a high temperature it can be cooled down without depositing any of the solid. At this reduced temperature, then, the liquid holds more of the solid than it could take up or dissolve at that reduced temperature. A liquid may be supersaturated with a gas, as, when in addition to its own volume of carbonic acid which water dissolves, it is, under the influence of pressure, made to take up another volume of the gas, as in the case of soda water, champagne, &c. Again, a liquid at or near the boiling point is a supersaturated solution of its own vapour, and, in all three cases, the salt, or the gas, or the vapour can be separated from solution under the influence of nuclei. (See *Nucleus*.)

Supersaturated saline solutions possess remarkable properties. A solution of sodic sulphate (Glauber's salt) for example, saturated at the point of maximum solubility (see *Solution*), and then boiled and filtered into clean vessels, may be preserved for a long time without any separation of salt, provided they be protected from the action of nuclei. For this purpose, all that is necessary is to plug the vessels with cotton wool, or even to cover it lightly with a watch glass, the former being the more efficacious, in which case the air of a room, being full of nuclear particles in passing between the fibres of the cotton wool, has these nuclear particles separated,

the air itself not being a nucleus In this way highly supersaturated solutions of hydrated sodic salts, such as the acetate, arseniate, succinate, sulphate, borate, as well as the sodic-potassic tartrate, potash and ammonia alums, magnesic sulphate, baric acetate, cupric sulphate, and many others, may be reduced to low temperatures without change, provided nuclei be rigidly excluded, as by keeping the vessels and the solutions chemically clean Various solid and liquid bodies, which act as nuclei in their ordinary condition, cease to be such if boiled up with the solution, and allowed to cool down with it in covered vessels In such case, the cold solution adheres to these bodies as a whole, and there is no separation of salt So also, if an oil be dropped into a cold supersaturated solution, and it remain in the lenticular form, it does not act as a nucleus, because its surface tension separates it from actual contact with the solution, or rather the tension of the surface prevents the adhesion of the watery particles from being weaker than that of the saline molecules or *vice versa*, which is a necessary condition of nuclear action (See *Nucleus*) But if the oil, on being deposited on the surface of the solution, spread out into a film, this film being in closer contact with the solution, from its diminishing its surface tension, acts powerfully as a nucleus, large crystals of the salt falling from the under surface of the film, until the excess of salt over saturation has been separated Thus matter, in the form of films, acts as a nucleus, and this is the very form in which bodies that have been handled or exposed to the air contract nuclei A glass rod, for example, drawn through the hand, becomes covered with a film of organic matter, and is a powerful nucleus On passing it through flame, or boiling it up with the solution, it loses this film, and is inactive in separating salt, or gas, or vapour from solution

Supersaturated saline solutions of hydrated double salts, contained in clean covered vessels, may be reduced to from 0° F to – 10° F, when they form unstable hydrates in tetrahedral crystals, but as soon as the temperature is raised to 32° F, these hydrates melt rapidly, and form clear bright supersaturated solutions as before, effects which can be produced any number of times, provided the action of nuclei be excluded

There are some salts which form modified hydrates of a more permanent charactor than those just referred to, such as the sodic sulphate, which in its normal condition contains ten atoms of water of crystallisation If a hot saturated solution of this salt be cooled down in a covered vessel to about 40° F, and still better if lower, it throws down anhydrous salt in the form of octahedra, if the temperature rise a few degrees, these octahedra pass into solution, and form a dense lower stratum, from which crystallises out a modified salt in prisms, with oblique summits, containing only seven atoms of water of crystallisation, while the solution above is still one of the anhydrous salt If now the cotton wool be removed from the vessel, the salt crystallises from the surface, and crystalline lines of the ordinary ten-atom salt proceed downwards, carrying with them sufficient water to convert the lower seven atom salt into the ten atom

There are many other points connected with supersaturation, some of which have already been noticed under *Nucleus*, *Ebullition*, &c We may also refer to Mr Tomlinson's papers, Phil Trans, 1868, Proc Royal Society, No 122, 1870, Phil. Mag, and Chem. News

SVALOCIN The star α of the constellation Delphinus This name, used in the Palermo catalogue, seems to be merely the inversion of Nicolaus

SYLVINE See *Potassium, Chloride*

SYMBOLS, ASTRONOMICAL In astronomy a number of symbols are made use of for purposes of convenience The origin of these symbols is not known, and many different interpretations have been given of the symbols themselves For example, the symbol for Capricornus, ♑, has been thought by some to be intended for a rough representation of the sea goat figured in star maps, while others insist that it is formed from the Greek letters τρ, for τράγος, *a goat* Again, the symbols of the five planets known to the ancients have been thus interpreted — ☿ is the petasus of Mercury, ♀ the mirror of Venus (?), ♂ the shield and spear of Mars, ♃ the throne of Jupiter, ♄ the sickle of Saturn (Cronus, or Time) But others find in these symbols the initial letters of various adjectives indicating the attributes of the several deities associated with these five planets Yet others find in ♃ the Zeta of Zeus, and in ♄ the K of Kronus Some find in ♃ and ♄ the Arabic numerals 4 and 5, indicating that these are the fourth and fifth planets of the ancient series In fine, there is no end to the interpretation of these symbols by means of letters and numerals (See the Delphin edition of Manilius) It would be difficult to form a conclusive opinion where so many different views have been adopted, but certainly one is invited by the resemblance between ☿ and the *petasus* as by that between ♂ and the arms of Mars, to conclude that among the symbols of the planets, as certainly among the Zodiacal signs, a rough attempt at pictorial illustration was the real origin of these figures

The following are the principal symbols now in use .—

Symbols of the Heavenly Bodies.

The Sun,	☉	Jupiter,	♃
Mercury,	☿	Saturn,	♄
Venus,	♀	Uranus,	♅
The Earth,	♁ and ⊕	Neptune,	♆
The Moon,	☾	A comet,	☄
Mars,	♂	A star,	✱

The Asteroids

Ceres,	⚳	Juno,	⚵
Pallas,	⚴	Vesta,	⚶

The attempt to give symbols to these bodies was continued until upwards of twenty had been discovered, when the necessity of employing a simpler mode of indicating them was recognised All the symbols were therefore abandoned, (except the four given above, which are still in use,) and the asteroids are now indicated by a number indicating the order of their discovery, the number being inclosed in a small circle Thus, the symbol (64) represents Angelina, the sixty-fourth asteroid in order of discovery

Lunar Phases

● Moon, in conjunction with the sun, or *new*
☽ Moon, at eastern quadrature, or *first quarter*.
○ Moon, in opposition to the sun, or *full*
☾ Moon, at western quadrature, or *last quarter*.

Signs of the Zodiac

Aries,	♈	Libra,	
Taurus,	♉	Scorpio,	♏
Gemini,	♊	Sagittarius,	♐
Cancer,	♋	Capricornus,	♑
Leo,	♌	Aquarius,	
Virgo,	♍	Pisces,	

Planetary Positions

	Ascending node	E □	Eastern quadrature
	Descending node	W □	Western quadrature.
	Conjunction	△	Trine
	Sextile	☍	Opposition.
□	Quadrature.		

Uranographical

R A or AR (sometimes also α) Right ascension	m	Minute of time.
Dec (sometimes δ) Declination	°	Degree
N P D North polar distance.	′	Minute of arc
h, Hour	″	Second of arc

SYMPIEZOMETER (συμπιέζω, to compress μέτρον, measure) An instrument for measuring the barometric pressure by the compression of air or gas It was invented by Mr Adie, and consists of a glass tube about 18 inches long and ¼ inch in diameter, with a closed chamber at the top, and an open cistern resembling that of an ordinary barometer below The cistern and the lower part of the tube are filled with glycerine, the closed chamber and the upper part of the tube being filled with common air As the pressure of the external air increases or diminishes the glycerine rises or falls in the tube At first oil of almonds was used in place of glycerine, and hydrogen gas in place of air, but the gas was partially absorbed by the oil. The glycerine, in the present form of the instrument, requires to be of a particular character, or it will absorb part of the air within the tube The indications of the instrument must be corrected for the effects of temperature, for which purpose a common thermometer is attached to the instrument

SYNAPTASE. See *Emulsin*

SYNODICAL (σύν, together, ὁδός, a journeying) In astronomy the interval separating successive conjunctions or successive oppositions of a superior planet, or successive conjunctions

of the same kind, in the case of an inferior planet, is called the synodical period of the planet. The moon's synodical periods are the same as her lunations

SYNTHESIS (σύν, together, and θέσις, a placing) The formation of chemical compounds from their elements or from bodies of less complex composition It is the opposite to *Analysis*

SYREN The Syren of Cagniard de Latour is an instrument for exhibiting the connection between the pitch of a note (see *Pitch*), and the number of impulses given to the air in a given time It consists of a brass cylindrical box, into one end of which air can be forced from an organ bellows The opposite face of the cylinder is pierced by one or more rings of holes concentric with the centre of the pierced face These holes are not bored in a direction parallel to the axis of the box, but obliquely through the thickness of the brass By means of studs and levers working through the side of the cylinder one or more of these rings of holes can be opened by removing plates which close their inner extremities In very close proximity with the upper face of the box is a circular brass disc of the same size, which turns with great ease around its centre This disc is perforated by rings of holes of the same nature as those in the top of the box, but the inclination of the holes is in the opposite direction If the inclination of both sets of holes is 45° the two sets will be at right angles to one another The axis of the upper moveable disc is a spindle which carries an endless screw This screw works into the cogs of a little wheel, so that when the upper disc turns round once the spindle turns round once, and consequently the wheel is turned round through the distance between two cogs The axis of this wheel bears an index passing over a graduated face or dial plate It also bears a pinion working in the cogs of a second wheel, whose axis also bears an index working over a dial plate By this means the second wheel will turn round more slowly than the first, according to the ratio of the number of cogs in the wheel and pinion The arrangement is in fact very similar to that connecting the hour and minute hands of a clock There is also an arrangement by which the first wheel can be slipped into and out of gear with the endless screw Let each dial plate be divided into a hundred divisions, and let the connecting gear be such that the second wheel and index turns round a hundredth of a revolution when the first wheel and index turn round once So that the units and tens of revolutions of the spindle are measured on the first dial plate, the hundreds and thousands, up to ten thousand, on the second Let us suppose that the syren is used for measuring the pitch of a tuning fork The fork is kept continually sounding its fundamental note by an assistant who strokes it with a fiddle bow The screw on the spindle is set out of gear with the toothed wheel The positions of the indices on the two dial plates are noted One of the studs is pushed in so as to open one ring of holes in the upper face of the cylindrical box, say that which contains n holes Air is then forced into the box from the bellows, its elasticity causes it to escape through the oblique holes, it strikes the oblique hole in the moveable disc at right angles, and since these are inclined at an angle of 45° to the horizontal, the resolved portion of its force in a horizontal direction is $\frac{1}{\sqrt{2}}$ of its impact This horizontal force, acting in a tangential direction, sets the disc spinning The same takes place at each opening When, therefore, the disc turns round once, there are n puffs of air escaping through the disc As the air is urged in, the upper disc increases in its velocity, and a note of higher and higher pitch is produced (See *Pitch*) When the note produced by the syren approaches that of the fork, rapid beats are heard (See *Beats*) When the pitches of the two notes are identical, these beats disappear This consonance is maintained for some time, conveniently until the commencement of a minute, as indicated by the second hand of a watch The screw on the spindle, and the tooths on the wheel, are instantly thrown into gear, and the bellows worked, so that no beats occur After the lapse of exactly a minute the screw is thrown out of gear, and the readings on the dial faces noted Let this reading indicate m revolutions Since n puffs are produced by one revolution, the number of puffs per minute corresponding with, and giving rise to a note of identically the same pitch as that of the tuning-fork is $m \times n$, or $\frac{m \times n}{60}$ is the number of vibrations of the fork per second The syren has its name from the circumstance, that it produces a musical note when water instead of air is forced through it, the whole instrument being under water

The syren of Seebeck is of much simpler construction, and may be used to show roughly the relation between rapidity of sequence of impact and pitch A circular sheet of cardboard is perforated with holes in two concentric rings, the outer ring containing twice as many holes as the inner one This can be turned with great velocity on its axis One end of a tube, open at both ends, is placed in the mouth, and the other above the inner ring of holes, and as close as possible to them On turning the cardboard rapidly round, and blowing through the tube, a musical note is produced, the pitch of which increases with the velocity of rotation If, while

the cardboard is being turned round with uniform velocity, the extremity of the tube be directed to the outer ring of holes, a note is produced an octave higher, showing that the relation between a note and its octave is the relation of one to two in the number of puffs which produce them

The first form of syren was that of Dr Robison, who caused a perforated plug to revolve in a tube through which air was forced, and who showed that the height of the note was increased with the rapidity of the vibrations

SYZYGY (συζυγία, conjunction) In astronomy, the conjunction of the sun, earth, and moon along one line, so that when the moon is new or full she is said to be *in syzygy*

T

TALBOTYPE PROCESS See *Calotype Process*

TALITHA (Arabic) The star ι of the constellation Ursa Major

TANGENT COMPASS A somewhat unusual name for the *Tangent Galvanometer*

TANGENT GALVANOMETER See *Galvanometer*

TANNIN (Tannic acid) Terms applied to amorphous astringent bodies found in galls and many varieties of bark They have a rough taste, a faint acid reaction, unite with animal membrane, albumen, and gelatin, forming insoluble non putrefiable compounds, and produce a dark blue or green colour with persalts of iron The commonest variety is gallotannic acid, which is obtained from oak apples, and Turkish and Chinese gall nuts Its formula is $C_{27}H_{22}O_{17}$

TANTALUM A very rare metallic element discovered by Ekeberg in a mineral from Sweden, called tantalite Its history, which is referred to under the heading *Columbium*, is the principal point of interest about it

TARAZED (Arabic) The star γ of the constellation Aquilæ.

TARTAR See *Tartaric Acid*

· TARTAR EMETIC See *Tartaric Acid*

TARTARIC ACID An organic acid widely diffused in the vegetable kingdom, especially in grape juice, where it occurs as acid tartrate of potassium There are five different tartaric acids known to chemists, which all possess the same composition ($C_4H_6O_6$), and scarcely differ from one another except in their action on polarised light, and in crystalline form When common tartaric acid is examined by a ray of polarised light it rotates it to the right But from some varieties of grape juice an acid called racemic is prepared, which scarcely differs chemically from tartaric acid, but has no action on polarised light It has therefore been called *Paratartaric Acid* By appropriate means, racemic acid has been separated into two acids, one of which is found to be ordinary tartaric acid, and the other an exactly similar acid, but possessing a left handed rotation This is called lævo tartaric acid When dextro and lævo-tartaric acids are mixed together they unite and form racemic acid The only one of these which requires detailed mention here is ordinary tartaric acid, also called *dextro tartaric acid* This crystallises in monoclinic prisms, which are colourless, transparent, and very soluble in water and alcohol It unites with bases to form salts, which are usually of two kinds, neutral and acid These, for the most part, crystallise easily in large, well defined crystals Tartaric acid also forms numerous double salts The following are the more important tartrates —*Bi-tartrate of Potassium*, or cream of tartar ($C_6H_5HO_6$), is difficultly soluble in water, and separates from its hot solutions in small trimetric crystals In the crude state it is called *Argol*, or *Tartar*, and is deposited from many kinds of wine on keeping It unites with soda to form a double salt, which crystallises in large rhombic prisms, readily soluble in water The composition is ($C_8H_4KNaO_6\,4H_2O$) It is sometimes called Rochelle salt *Potassio Antimonious Tartrate* is of considerable use in medicine, under the name of tartar-emetic Its composition is $C_4H_4K(SbO)O_6\,\frac{1}{2}H_2O$, and it crystallises in octahedrons, which are tolerably soluble in water

TARTARIC ACID, RIGHT-HANDED AND LEFT-HANDED See *Right-Handed and Left-Handed Tartaric Acid*

TAURUS (The Bull) A sign of the Zodiac The sun enters this sign on about the 20th of April, and leaves it on about the 21st of May The constellation Taurus occupies the zodiacal region corresponding to the sign Gemini This constellation is exceedingly rich It includes those remarkable star groups, the Pleiades, and the Hyades, and many singularly rich telescopic fields Sir John Herschel considers that a branch of the Milky Way may perhaps be traced from Perseus as far as the Pleiades

TAUTOCHRONE (ταὐτό for τὸ αὐτό, just the same, and χρόνος, time) A curve such that a particle moving under the action of given forces will reach a given point in the same

time, wherever may be the starting point A particle falling under the action of gravity from rest down the arc of a cycloid will reach the lowest point in the same time, whatever be the point of the curve from which it starts. Hence the cycloid is the tautochrone for the force of gravity

TEINOSCOPE (τεινω, to spread out; and σκοπεω, to view.) Another name for the *prism telescope*, which see

TELEGRAPH, ATLANTIC See *Atlantic Telegraph.*

TELEGRAPH, ELECTRIC (τῆλε, at a distance, γράφω, to write) From the earliest time, when beacons lighted on the tops of the hills were used to indicate the approach of an enemy, or the occurrence of some other important event, the power of communication at a distance has been felt to be a desideratum Many inventions and arrangements have from time to time been made with this object, as, for example, the signals by flags, or by the old semaphore system, which is still employed for railway signalling, by ringing of bells, or by the motion of water in tubes, but none of these was applicable to any but short distances, or indeed generally applicable at all The discovery of the conduction of electricity along metal wires, however, soon gave rise to the idea of communicating signals by means of its effects, and the electric telegraph has now become one of the most powerful agents for the promotion of civilisation, and even a necessity of every-day life

The first electric telegraphs proposed were founded on the observation of motions produced by the attraction or repulsion of statically electrified bodies In 1747 Watson showed the transmission of a discharge from a Leyden jar through a wire stretched across the Thames, and later in the same year he caused it to pass through 10,600 feet of wire supported on insulators, which were attached to wooden posts In 1753 there appeared in *Scot's Magazine* a letter signed C M, in which the idea of signalling by means of electricity is originated, and during the next seventy years many different methods of telegraphing were proposed It was not, however, till after the discovery of the electric current by Galvani, and of the effect of a current upon a magnetised needle in its vicinity by Oersted, and till after the establishment of the fundamental laws of electric dynamics by Ampère in 1820, that the idea of electric telegraphy was acknowledged to be practically useful, but immediately after this, and after the discoveries of Faraday in electro-magnetism, various schemes, more or less practical, were proposed to take advantage of the motions of a magnetised needle in the neighbourhood of a current as a means of signalling The names of Sommering, Schweigger, La Place, Fechner, Ritchie, and Baron Schilling, are connected with the first attempts to telegraph by means of galvanic electricity The method of the first two was based upon the decomposition of water by means of the pile. Gauss and Weber, for the purpose of studying the laws of the action of galvanic currents, set up a long line of two wires from their Physical Cabinet in Gottingen to the Observatory This was the first line in which a single wire was employed, most of the other systems requiring a wire for each letter, or at least a particular pair out of several wires to indicate a letter The signals also were given by means of magneto-electricity, which had not been employed before. Gauss and Weber did not, however, employ the line, in the first instance, for telegraphic purposes, though they afterwards used it in that way, and subsequently, Professor Steinheil of Munich was requested by them to perfect the arrangements, and make them capable of more practical use Hence, and from the ingenious inventions and improvements of Steinheil, arose the system of telegraphy which bears his name The messages were printed by means of dots made in proper positions on strips of paper which were kept in uniform motion by clockwork. Steinheil afterwards discovered that two wires were unnecessary, and that a complete circuit might be made by using one wire and permitting the current to return through the earth But telegraphy is not indebted to any more than to Messrs Cooke and Wheatstone, (now Sir Charles Wheatstone), who, joining their inventions together, produced, with great ingenuity and perseverance, a system capable of practical application A telegraph was established by them on the London and Birmingham and Great Western Railway lines, and subsequently, their system, modified and simplified by themselves, and made much less expensive, has been largely adopted for inland telegraphy

Our limits will not permit us more than this brief sketch of the history of telegraphy We have not even been able to mention the names of all the many who contributed to the progress of the invention, but it will be seen from what we have said that the invention of telegraphy cannot be claimed, as has frequently been done, for or by any one man or set of men A multitude of investigators, inventors, and practical men have assisted in the development of the system

We shall now briefly explain the method of telegraphy details can readily be obtained by the interested reader from the many practical works upon the subject, and among others, from those of Mr. Robert Sabine. Of the line in submarine telegraphs we have given a description

nder *Cable, Submarine* The wires used for overhead lines are of iron Various ways of protecing them from rusting have been proposed and employed The best plan is probably that of arnishing them with boiled linseed oil, or painting them with tar from time to time till a olerably thick coat is accumulated, which protects them from moisture and from the ontact of the air Galvanized iron is sometimes employed, but in the neighbourhood of large owns where acid fumes are to be found in considerable quantity, the zinc coating is soon estroyed The wire is supported by means of telegraph posts which, in England, are made of vood It has been proposed to use stone pillars, and this was done to some extent in India The stone pillars are much more durable than wood, but the expense of constructing them has revented their adoption In Switzerland iron posts have lately been employed and their use vill probably become more general The wire is attached to *insulators* which are fixed to the osts Of these there are various kinds In England that of Mr Latimer Clarke is much mployed It is a double bell made of porcelain and of a shape suitable to allow rain to run off it vithout wetting the inside The bell is supported by a stem proceeding from the top of the nterior of it, and the line wire passes through a deep groove at the top of the bell, and is secured n its place by means of binding wire In underground lines the wires are insulated by a guttaercha or other non-conducting covering and are now contained in iron pipes laid under the avement or along road-ways In Paris they pass through the sewers and catacombs, those in he sewers being enclosed in lead tubes for protection from the destructive gases

For sending and receiving messages, various forms of instruments are employed, the choice lepending upon the purpose for which they are used and on the length of the line On long ubmarine lines as is explained (see *Atlantic Telegraph*, *Mirror Galvanometer*, &c), the reflecting galvanometer of Sir William Thomson is universally and at present necessarily employed, hough it is probable that a newly invented self-recording instrument, also by Sir W Thomson, vhich has already been tried on the French Atlantic and on the Cornwall and Lisbon lines vill shortly be in general use In this instrument a very light coil of wire is very delicately uspended in a magnetic field, and the motions of it when a current is passed through it are the neans whereby the messages are transmitted The coil of wire is attached to a very light iphon of glass through which the ink from a reservoir flows The siphon is a capillary tube of xcessively small dimensions, and the ink is drawn from it by electric attraction, the reservoir nd the paper being oppositely electrified The extremity of the siphon is not in contact with he paper but only near to it The delicacy and rapidity of the instrument are even greater than hat of the mirror galvanometer, and the recording of the messages is felt by telegraph companies to be of the highest importance On land lines and short submarine lines the needle elegraph of Wheatstone and Cooke and the recorder of Professor Morse of New York are nuch employed In the needle telegraph of Wheatstone and Cooke a pair of needles is used, one of which is magnetised and placed within a multiplying coil the arrangement being similar to that of the ordinary astatic galvanometer or multiplier but the plane of the coils is vertical and the needles are suspended on a horizontal axis about which the pair turns The axis of suspension is but ittle above the centre of gravity of the system The other needle appears at the face of the instrunent and deflects its upper end to the right or left of the vertical line, according to the direction n which the current passes A certain number of deflections to the right or left, or of deflecions some right and some left, in particular order, indicates a given letter, number, or word. Frequently a *double needle* telegraph instrument is employed, which consists of two single needle nstruments in the same case The letters are formed by combinations of indications from the wo needles, and as there are thus four motions, a right and a left of each needle, it is evident hat the speed of signalling is immensely increased The necessity of two lines, however, makes he use of it too expensive for general purposes The messages are sent by means of a very imple commutator or reversing key, which is worked by a handle to be seen on the face of the nstrument below the dial, over which the needle moves When the handle is in the vertical osition, the instrument is in condition for receiving The turning of the handle in one direcion or the opposite, gives rise to a current of electricity from the battery, which passes both hrough the instrument of the receiver and through that of the sender The attention of the eceiver is called by a preliminary sounding of an electric bell.

In the Morse recorder the receiving instrument consists essentially of a soft iron bar, which s magnetised and demagnetised by the passage and stoppage of the current, and a soft iron rmature, which is attracted each time the other is magnetised, and freed when it is demagnetised The armature is connected with one end of a lever, and to the other end of the lever s attached a style or an ink marker, which is pressed upon the paper at each attraction of the rmature The paper is a long slip, which is drawn past the point of the marker at a uniform ate by clockwork The signals are made by combinations of a dot and a dash (a short and a ong mark) on the paper, the dot being made when the current merely passes round the electro-

magnet for an instant, the dash when the current is of some duration The sending instrument is a lever which, on being pressed down, permits the current from the battery to flow into the line during the time that the contact is made

On applying the Morse instrument to a long line, it was found that the current is frequently so weak that it cannot move the armature, hence Morse connected with the instrument a *relay* and *local battery* The relay consists of a pair of electro-magnet coils, through which the line-current passes The only work that these coils require to do is to draw down a light armature, and the motion of this armature, by means of a lever, closes a local circuit containing a battery and the Morse instrument Thus, on every passage of the current through the line wire, a current is caused to flow from a local battery through the instrument, and the work required to be done by the line-current is very small indeed, being merely the motion of the key of the local circuit at the receiving end

In private lines, instruments known as "dial telegraphs" are employed, from the case with which they are manipulated They consist of two parts, a transmitter, which is a dial marked with the letters of the alphabet, either on keys which the sender presses, or on a plate over which a handle passes By mechanical arrangement the current is made through the intervention of electro-magnets to turn a pointer at the receiving end, which moves over a dial on which also letters are marked, and at each signal from the sender, the pointer stops at the letter sent There are various forms of dial telegraphs. Wheatstone's step by step instrument has perhaps the most general employment

TELEPHONE (τῆλε, afar, and φωνή, a sound) An arrangement for telegraphing in which the letters are indicated by sounds It consists of two parts, a sending instrument and a receiving instrument In the sending instrument a stretched membrane is made to vibrate by means of sounds produced in front of it, and vibrates at rates depending upon the pitch of the note played At each vibration contact is made, and broken with a battery, and by a proper arrangement, electric signals, whose number corresponds with the note played are sent through the line At the other extremity the current circulates round a bar of soft iron, which is thus rapidly magnetised and demagnetised The demagnetisation gives rise to the sound known as the magnetic tick (see *Sounds, Magnetic*), and these sounds occurring with the same rapidity as the vibrations produced at the other end, give rise at the receiving end to the required note

TELESCOPE (τῆλε, at a distance, and σκοπεω, to see) An optical instrument for viewing objects at a distance It consists essentially of an achromatic *object glass*, or a *concave speculum*, which forms an image of the object to be viewed at its focus. This image is then magnified by a simple microscope in the form of an eye-piece. For astronomical purposes, where it is of no consequence if the object is inverted, an *astronomical eye piece* is used, otherwise an *erecting* or *terrestrial eye-piece* is more general (See *Achromatic Telescope, Object Glass, Speculum, Astronomical Eye piece, Erecting Eye piece, Reflecting Telescope, Galilean Telescope*)

TELESCOPE, MAGNIFYING POWER OF The magnifying power of a telescope may be ascertained by dividing the focal length of the object glass by that of the eye-piece It may be roughly seen by looking at a distant object through the telescope, and viewing the object at the same time with the other eye. The two images will then appear side by side, and their respective diameters can be compared

TELESCOPE, PRISM See *Prism Telescope*

TELESCOPIUM (The Telescope) One of Lacaille's southern constellations

TELLURIC LINES OF THE SOLAR SPECTRUM. See *Atmospheric Lines of the Solar Spectrum*

TELLURIUM (*Tellus*, the earth) An element belonging to the sulphur group, and approaching in character a metal It was discovered by Klaproth in 1798, physically it strongly resembles the metals, it is tin white, shining and metallic looking, crystallising readily, and very brittle It is a bad conductor of heat and electricity Specific gravity, 6 3 Atomic weight, 128, Symbol, Te It melts at 500° C (932° F), and at a higher temperature volatilises When heated in the air it takes fire with a blue flame In its chemical properties it strongly resembles sulphur and selenium, like them it forms two oxides, *tellurous acid* (TeO_2), and *telluric acid* (TeO_3), which unite with bases, and form salts which are analogous to the corresponding salt containing sulphur and selenium It forms *telluretted hydrogen* (TeH_2), which closely resembles sulphuretted and seleniuretted hydrogen, and its compounds with other elements strictly carry out the analogy

TEMPERAMENT IN MUSIC See *Gamut.*

TEMPERATE ZONE See *Climate*

TEMPERATURE (*Temperatura, tempero, tempus*, from τεμνω, to cut; strictly a portion cut or measured off, thus *time*) The temperature of a substance is the amount of sensible heat

associated with it By sensible heat we mean heat which can be recognised by a thermometer, and which is capable of passing to other substances, and of effecting the various changes in them which heat is wont to produce When a substance is heated its temperature is said to increase, when it is cooled its temperature is said to decrease Temperature is not the *quantity* of heat associated with a substance, for a drop of water may possess the temperature of an ocean, while the absolute quantity of heat possessed by the latter will obviously be infinite compared with that possessed by the former In the case of a unit of heat (1 lb of water raised through 1° F), we have a definite amount of matter which has its temperature increased to a definite extent Two substances are said to be of the same temperature when, on being placed in contact, there is no change as regards their sensible heat, if they have different temperatures at the outset, the temperature which results from their being brought into contact differs from that which either of them at first possessed Temperatures are measured by the expansion of a solid, liquid, or gas, under appropriate conditions, and in instruments of divers forms, most usually by the expansion of a liquid in an instrument called a thermometer The standard temperatures to which others are referred are usually the freezing and boiling temperatures of water, other temperatures being expressed relatively to these The following are some remarkable temperatures, according to Fahrenheit's scale —

Absolute zero of temperature,	− 458°	Mercury boils,	662°
Greatest artificial cold,	− 220	Bright red heat,	1552
Greatest natural cold,	− 91	Silver melts,	1773
Mercury melts,	− 39	Gold melts,	2016
Ice melts,	+ 32	White heat,	2372
Wax melts,	144	Temperature of a blast furnace,	3280
Water boils,	212	Temperature of the voltaic arc,	3758
Sulphur melts,	239		

The greatest artificial cold has been produced by rapidly evaporating in a vacuum a mixture of liquid nitrous oxide (N_2O), and disulphide of carbon (CS_2) The greatest natural cold was observed by Hansteen in 55° N Lat The mean December temperature of Yakutsk is −44 5° F During some of the Polar Expeditions the cold has been so intense that mercury has been beaten out into thin plates The greatest heat with which we are acquainted is that of the Voltaic arc, the temperature of which, given above, is on the authority of Becquerel, but all extreme temperatures are incapable of being determined with any approach to the accuracy of more moderate temperatures (See also *Pyrometer, Thermometer, Absolute Zero of Temperature*)

TEMPORARY STARS, SPECTRA OF See *Variable and Temporary Stars, Spectra of*

TENACITY (*Tenax*, from *tenere*, to hold The property by which solids resist forces tending to separate their particles from one another It is divided into absolute and retroactive

Absolute tenacity is the resistance offered to a force tending to pull the particles of a body asunder, and overcome their cohesion It is estimated by the weights required to break rods or wires of the various substances when the weights are suspended from them

Muschenbroeck's experiments give the following results, interpreted thus —A rod of elm wood having a horizontal section of one fourth of a square line, breaks when a weight of 87 lbs is suspended from it, or a rod of elm, having a horizontal section of one fourth of a square centimetre, breaks with a weight of 918 kilogrammes —

Absolute Tenacity of	Horizontal Section = ¼ square line	Horizontal Section = ¼ square centimetre
Elm,	87 lbs	918 kilogs
Fir,	57−88 ,,	600−929 ,,
Oak,	110−140 ,,	1150−1466 ,,
Beech,	136−148 ,,	1349−1586 ,,
Copper Wire,	266 ,,	2782 ,,
Brass ,,	340 ,,	3550 ,,
Lead,	26 ,,	272 ,,
Tin,	43 ,,	457 ,,
Glass (white),	14−22 ,,	142−233 ,,
Hempen Cord,	34−60 ,,	350−360 ,,

Sickinger's experiments give the following as the ratios of the absolute tenacities of the metals —

Gold,	150,955 lbs.
Silver,	190,771 ,,

Platinum, . .	262,361 lbs.
Copper, . .	304,696 „
Soft Iron (Swedish),	362,927 „
Hard Iron, . .	559,880 „

The tenacity of metals usually diminishes as the temperature increases Iron, however, is an exception, its tenacity being greater at 200° C than at 100° C

Retroactive tenacity is the resistance offered to a force tending to crush a body.

The following weights were required to crush cubes of the substances—

One cubic inch of Elm, ...	1284 lbs.
„ Deal, ...	1928 „
„ Oak, ...	3860 „

Cubes of 1¼-inch Edge	Specific Gravity	Crushing Force
Chalk, ...	—	1,127 lbs
Red Brick, ...	2 168	1,817 „
Fire Brick, ...	—	3,864 „
Portland Stone, . . .	2 428	9,776 „
White Statuary Marble, . .	1 760	23,632 „
Cornish Granite, . . .	2 662	14,302 „
Dundee Sandstone, . . .	2 650	14,918 „
Compact Limestone, . . .	2 598	17,354 „
Black Marble, . . .	2 697	20,742 „
Aberdeen Granite, . . .	2 625	24,580 „
Cubes of 1¼ inch Edge		
Cast Iron, ...	—	9,773 „
Cast Copper, ...	—	7,318 „
Yellow Brass, ...	—	10,304 „
Wrought Copper, . . .	—	6,440 „
Cast Tin, ...	—	966 „
Cast Lead, ...	—	483 „

The following results were obtained with bars of the various metals, 6 inches long, and ¼ inch square, when suspended by nippers they were broken by the weights given in the table —

Cast Iron, horizontal, . .	1166 lbs	Hard Gun Metal, . . .	2273 lbs
Cast Iron, vertical, . . .	1218	Wrought Copper, . . .	2112
Cast Steel, . .	8391	Cast Copper, ...	1192
Swedish Iron, reduced by the hammer,	4504	Cast Tin, ...	296
English Iron, „ „	3492	Cast Lead, ...	114

The experiments of Stephenson, Fairbairn, and Hodgkinson on cast iron, showed the retroactive tenacity to be on an average 5 7 times greater than the absolute tenacity The latter, calculated from experiments on the resistance to direct tension, was found to be 10 to 11 kilogrammes for a square millimetre

Fairbairn and Tate have investigated the absolute tenacity of glass, with the following results —

Absolute tenacity, determined from resistance of glass globes to internal pressure —

Flint glass, specific gravity 3 078, . .	4200 lbs
Green glass, specific gravity 2 528, . .	4800 „
Crown glass, specific gravity 2 450 . .	6000 „

The resistance of glass to crushing was estimated by two methods, in the first, small cylinders were used, in the second, cubes of glass, which were crushed between parallel steel surfaces by means of a lever The results in the case of the cylinders are considered more accurate, as the cubes were cut from much larger portions of glass than the cylinders, and were probably less thoroughly annealed

	Mean Crushing Weight in lbs per square inch	
	For Cylinders	For Cubes
Flint glass, . . .	27,582	13,130.
Green glass, . . .	31,876	20,206
Crown glass, . . .	31,003	21,762

For Fairbairn and Tate's complete investigation, see Proceedings of Royal Society, x. 6 For

other papers connected with the subject, see Mr Rennie's paper on Resistances to Crushing, Phil Trans, 1818, Part I, and the "Britannia and Conway Tubular Bridges," London, 1850, for Stephenson, Fairbairn, and Hodgkinson's experiments on cast iron See also *Cohesion*

TENSION (*Tendo*, to stretch) See *Transmissibility of Forces*

TENSION, ELECTRIC A word employed to denote that property of the galvanic battery which gives rise to a current of electricity when the terminals of the battery are joined by a wire It is proportional to potential or difference of potentials The use of the word is, however, rather vague and considerably varied by different writers In speaking of statical electricity, it is frequently defined to be proportional to that which we have called electric density, that is, the quantity of electricity per unit area at a point, and sometimes as the force or pressure tending to effect discharge of an electrified body

TENSION OF LIQUID SURFACES It appears that the surfaces of liquids are in a somewhat higher state of tension than the interior portions, and that liquids may, therefore, when exposed to the air, be supposed to be inclosed in liquid films or skins No direct evidence has been gathered of the existence of such films, but certain phenomena can scarcely be explained on any other supposition The fact that a drop of a liquid may rest for a time on the surface of the same liquid points to a resistance to rupture of one, probably both surfaces The phenomena of movement, when certain volatile substances, such as camphor, are placed in contact with water, are now generally admitted to be due to the diminution of the tension of the superficial liquid film where it is in contact with the vapour of the substance That the liquid film, when approximately isolated, possesses great cohesion, is seen in the bubble, very perfectly exhibited in the glycerine-soap bubble A bubble covering a flat ring would itself be flat if not acted on by external forces, such as gravity, and, if the film be thin, it will have sensibly a flat form It is in this form, in fact, that the mean approximation of the parts to one another is greatest And the form is therefore determined by the exertion of cohesion It follows that when the form is disturbed so as to give the bubble film a curved surface, the effort to the plane will be always towards the convex side, and this effort will be greater on the same unit of surface for a small bubble than for a large one, because the departure from the plane is greater in the former than in the latter case The radius of curvature is less in the former than in the latter case The actual force exerted by the entire circumference of a bubble in contracting may be measured by blowing such a bubble on a tube, and plunging the other end of the tube in a vessel of water, when upon the effort of the bubble to contract will be measured by the depression, below the general level, of the surface of the water in the tube In the same way, the pressures exercised by a segment of a sphere may be determined by blowing such a bubble on the mouth of a funnel, the elongated neck of which is immersed in water Laplace and Poisson have proved that the figure of a closed bubble, when not acted upon by external forces, must be the spherical

TENSION OF VAPOUR See *Elastic Force of Vapour*

TERBIUM A very rare metal occurring with Yttrium and Erbium Its existence is, however, doubted by some chemists, and its compounds are almost unknown (See *Erbium*)

TERMINATOR In astronomy the boundary between the illuminated and dark portions of the moon's disc

TERRESTRIAL EYE-PIECE See *Erecting Eye piece, and Eye piece*

TERRESTRIAL TELESCOPE A telescope to which an erecting eye piece is attached so as to give an erect image

TEST OBJECTS Objects mounted for microscopic examination for the purpose of testing the defining and resolving power of object glasses Many natural objects are used as tests, such as the scales of the *Lepidoptera* and the *Podura* The most trustworthy test object, however, is a plate of glass ruled with parallel lines of various degrees of closeness Nobert's test plates are marvels of machine ruling, some of the lines being only the 1-100,000th of an inch apart (See *Microscope*)

THALLIUM (θαλλός, a green bud) A metallic element discovered by Crookes in 1861 by means of spectrum analysis In the pure state thallium is a white lustrous metal resembling cadmium in colour At the ordinary temperature, a freshly cut surface tarnishes instantly Specific gravity, 11 8 to 11 9, atomic weight, 203, symbol, Tl It is the softest metal which admits of free exposure to the air, being much softer than lead, it is very malleable, but only

of hydrogen

imparts an intense green to it, and its spectrum is seen to be absolutely mono-chromatic, consisting of an intensely brilliant and sharp green line, it therefore gives the simplest spectrum of any known element. Thallium is strongly diamagnetic, it forms two oxides—the *protoxide*

(Tl_2O), and the *sesquioxide* (Tl_2O_3) The former is soluble in water, and has alkaline properties It unites with acids, forming a well defined series of crystalline salts Metallic thallium is easily obtained by heating its compounds with reducing agents, in this respect it strongly resembles lead

THALLIUM, SPECTRUM OF When a compound of thallium, or a piece of the metal melted upon the end of a platinum wire, is held in a colourless spirit or gas flame, it imparts an intense green colour to the flame, and when this is examined in the spectroscope, its spectrum is seen to consist of a single green line The green light of incandescent thallium is therefore perfectly homogeneous (See *Spectrum Analysis*, *Monochromatic Light*)

THAUMATROPE (θαυμα, wonder, and τρέπω, to turn) A toy invented by Dr Paris, to illustrate the persistence of visual impressions on the retina Two images, having relation to each other (such as a jockey and a horse), are painted one on each side of a disc of cardboard By means of two strings, the disc is then put into rapid rotation when the images become superposed on the retina, and the jockey appears to be seated on the horse (See *Persistence of Vision*)

THEINE An organic substance extracted from tea, it is chemically the same as Caffeine (*q v*)

THEORY OF EXCHANGES In discussing the reflection of heat, we have described an experiment in which two parabolic mirrors are placed face to face, when a source of heat in the focus of one of them causes an indication of reflected heat in the other by the ignition of inflammable substances In place of the source of heat, Pictet placed a piece of ice in the focus of a mirror, and observed that a thermometer in the focus of the opposite mirror indicated cold, in fact, cold appeared to be reflected like heat In speculating on the cause of this, Professor Prevost was led to propound his *Theory of Exchanges*, which was first made known in 1791, through the medium of the *Journal de Physique* According to Prevost, we have in the above experiment no reflection of cold, an interchange of heat is perpetually going on between all substances, they are radiating heat, and if they radiate more than they receive, the temperature falls, while, if they receive more than they radiate, the temperature rises When a source of heat is placed in the focus of a mirror, and a thermometer in the focus of an opposite mirror, the mercury rises because the thermometer receives more heat than it emits, when ice takes the place of the source of heat the mercury falls, because it gives out more heat than it receives Even substances, which are at the same temperature, are supposed to be radiating heat to one another, and their temperature remains unchanged, because they radiate *to* surrounding substances, just as much heat as they receive *from* surrounding substances This was called by Prevost a condition of *mobile equilibrium* of temperature There is a perpetual communication of the motion called heat to the ether, and absorption of it from the ether, and when a substance gains more than it loses, it becomes heated, while, when it loses more than it gains, it becomes chilled A very complete account of the more recent developments of the theory of exchanges is given by Dr Balfour Stewart in his *Treatise on Heat*, in which he shows that radiation of heat takes place, not only exteriorly from surface to surface, but also within them "In the interior of substances, as well as in the air or vacuo, a stream of radiant heat is constantly passing and repassing in all directions, and, in the case of constant temperature, as this stream of heat passes any layer of particles, it is just as much diminished by the absorbing action of these particles, as it is recruited by their radiation, so that the stream flows on virtually unchanged both in quantity and quality, until at last it reaches the surface"

The same authority has put Prevost's theory of exchanges into the following concise forms —

"1 If an enclosure be kept at an uniform temperature, any substance surrounded by it on all sides will ultimately attain that temperature

"2 All bodies are constantly giving out radiant heat, at a rate depending upon their substance and temperature, but independent of the substance or temperature of the bodies that surround them

"3 Consequently, when a body is kept at an uniform temperature, it receives back just as much heat as it gives out"

THERMAL CONDUCTIVITY See *Conduction of Heat*

THERMAL RESISTANCE See *Conduction of Heat*

THERMAL UNIT (θέρμη, heat, *unus*, one) See *Unit of Heat.*

THERMO-DYNAMIC ENGINE See *Heat Engine*

THERMO-DYNAMICS (θέρμη, heat, δύναμις, force) We have elsewhere stated that heat is convertible into mechanical work, and *vice versa* Now the laws which regulate these changes, and which bind them together into one systematic whole, constitute the science of *Thermo dynamics* In the article *Heat* we have traced the rise of this science, and discussed certain phenomena connected with it, both there and in treating of the *sources of heat.*

We may here mention some of the deductions of Rankine, Clausius, and Sir W Thomson, who have done much to develop this science The original memoirs of Clausius are, for the most part, in *Poggendorff's Annalen*, between 1850–60, while those of Rankine and Thomson are in the *Philosophical Transactions*, the *Transactions of the Royal Society of Edinburgh*, the *Philosophical Magazine*, and elsewhere They contain a full mathematical treatment of various branches of the subject, which we cannot reproduce here Professor Rankine defines the first law of thermo dynamics as follows —"Heat and motive power are mutually convertible, and heat requires for its production, and produces by its disappearance, motive power in the proportion of 772 foot pounds for each Fahrenheit unit of heat This law may be considered as a particular case of the application of two more general laws, viz —1 All forms of energy are convertible 2 The total energy of any substance or system cannot be altered by the mutual action of its parts" The second law he defines thus —"If the total actual heat of a homogeneous and uniformly hot substance be conceived to be divided into any number of equal parts, the effects of those parts in causing work to be performed will be equal"

The application of certain principles of thermo dynamics to various phenomena of the universe has been before alluded to in connection with the origin of the heat of the sun, and Sir W Thomson has treated the meteoric theory of the sun mathematically with great skill Although the heat of the sun may have been originally produced by the collision of meteoric matter, he does not consider that it can be so maintained He has calculated the following table, which shows the amount of heat of gravitation—that is, heat which would be produced, by the collision of the various bodies named, with the sun, in terms of the total solar emission —

	Heat produced equal to the total emission of heat from the sun for
Mercury,	6 years, 214 days
Mars,	12 ,, 252 ,,
Venus,	83 ,, 227 ,,
Earth,	94 ,, 302 ,,
Uranus,	1610 ,,
Neptune,	1890 ,,
Saturn,	9650 ,,
Jupiter,	32,240 ,,

That is to say, if the earth fell into the sun, the quantity of dynamic energy, which it possessed when in motion, would, when converted by the collision into heat, be sufficient to provide for the total solar emission for nearly 95 years, and the heat, resulting from the fall of all the above planets into the sun, would provide for the solar emission for 45,585 years (See also *Heat*, *Heat, Sources of*, *Mechanical Equivalent of Heat*)

THERMO-CURRENT The current produced by heating unequally a compound circuit, consisting of two or more different metals, is called a thermo-current (See *Thermo electricity*)

THERMO ELECTRIC BATTERY See *Battery, Thermo electric*

THERMO ELECTRICITY Electric excitement results, under certain circumstances, from the action of heat, and the effects thus produced are treated of under two heads, *Pyro electricity*, and *Thermo electricity*

Seebeck, in 1821, found that on raising the temperature of one of the junctions of a circuit, composed of two or more metals above that of the other junctions, an electric current is generated, the direction of which depends upon the nature of the metals used, and he called such currents *thermo-electric* The same is true if one of the junctions be cooled Becquerel showed that if to the extremities of a delicate galvanometer coil be attached the ends of a platinum wire, on which a knot is tied, and if the wire be heated near to the knot, a current is produced, whose direction changes according as the heat is applied on one side or other of the knot In fact, in any non homogeneous circuit, if heat be applied near to a place where want of uniformity and irregularity begins, a current is set up Let a copper wire have one of its ends twisted together with an iron wire, and let the other extremities of this pair of metals be attached to a galvanometer, then on nearing the point at which the copper and iron are in contact, a current is produced, which flows, unless the heat be too great (see below) from the copper, to the iron through the heated point Or, again, if a piece of copper wire be cut in two, and if one of the ends of each half be attached to the galvanometer, then on heating one of the free ends, and pressing it against the other, a current is at once set up, which passes from the hot to the cold through the junction Or in a wire, one part of which has been hammered, twisted, or otherwise strained and the other not, or if one part has been annealed, and the other not, a current is always obtained when heat is applied at the place where change of molecular structure begins

As we have said, when one junction of two metals is kept at a different temperature from

the other, a current is generated The direction of the current, and the electromotive force depend upon the nature of the metals, and also to a certain extent upon the temperature at which the whole circuit is before one of the junctions is made to vary from it For any one temperature a table may be constructed, in which the metals are arranged in order, such that any two of them being taken together, and one of the junctions varied a little from that temperature, the direction of the current is indicated by their position in the table Mathiessen gives the following —

COLD

Bismuth,	25
Cobalt,	9
Potassium,	5 5
German Silver,	5 2
Nickel,	5
Sodium,	3
Mercury,	2 5
Aluminium,	1 3
Magnesium,	1 2
Lead,	1 03
Tin,	1
Copper,	1
Platinum,	0 7
Silver,	0
Gas Coke,	− 0 05
Zinc,	− 0 2
Iron,	− 5
Antimony,	−10
Tellurium,	−179

HOT

This table gives the order of the metals between 40° and 100° F The arrows indicate the direction of the current through the *hot* or the *cold* junction, and the numbers express the electromotive force of different pairs of metals compared with that of a copper and silver pair taken as unity For example, the current between a pair of wires of German silver and aluminium would flow from the former to the latter though hot, and the electromotive force is found by taking the difference of the numbers 5 2 and 1 3, that is, it equals 3 9 times the electromotive force of a copper and silver pair Again, the electromotive force between German silver and iron is 5 2 − (− 5), or 5 2 + 5, or 10 2 It appears, therefore, that the best effect would be obtained from a pair of bismuth and tellurium, we should obtain from them an electromotive force of 204 Tellurium is however very difficult to obtain, and bismuth and antimony are always made use of in constructing thermo electric batteries (See *Battery*, and *Thermopile*)

Thermo-electric Inversion The table just given expresses, as we have said, the order of the metals at a particular temperature Cumming, in 1823, discovered that the order of the metals depends upon the temperature at which the experiment is made, but his observations and those of Becquerel on the same subject attracted little notice till the matter was taken up by Thomson The last named added to the list already commenced a large number of new cases of thermo electric inversions, and by his discovery of *electric convection* of heat threw a new light upon the subject The phenomenon of inversion is easily shown Let a compound circuit of copper and iron be attached to the galvanometer, and at common temperature let one of the copper and iron junctions be heated above the other, the current will pass, as indicated by the list which we have given above, from copper to iron, through the hot junction Now, let both junctions be warmed up to 550° F, a constant small difference being maintained between the temperatures of them, it will be found that at a certain temperature no current passes, and that above this temperature the current flows in the opposite direction, namely, from iron to copper, through the hotter junction In a paper published in the *Phil Trans*, 1856, Sir W. Thomson gives a diagram, in which the neutral points are displayed for a large number of wires, and he comes to the conclusion, that instead of a single list to show the direction and amount of the thermo-electric current, it is necessary to give a list at each particular temperature, or a series of curves to represent them. The following lists, at two temperatures, make this plain

Order at 0° C (32° F)	Order at 300° C (572° F)
Antimony.	Antimony.
Iron	Cadmium.
Cadmium.	Zinc
Gold	Gold
Silver	Silver
Platinum (1)	Copper
Zinc	Iron }
Copper	Brass }
Platinum (2)	Lead
Lead	Tin
Tin	Platinum (1)
Brass	Platinum (2)
Platinum (3)	Platinum (3)
Mercury	Mercury
Palladium	Palladium.
Nickel	Nickel
Bismuth.	Bismuth.

The three specimens of platinum marked (1), (2), (3), were probably alloyed to different degrees with other metals

Thermal effects produced by a current Peltier, in 1834, showed a phenomenon the converse of that which we have been concerned with On passing a galvanic current through a circuit composed of two different metals, he found that one of the junctions is heated, and the other cooled by it This may be exhibited in the following way —Let a circuit be formed of two bars of bismuth with one of antimony between them, and let a gentle current be sent through it, it will be found that the junction at which the current passes from bismuth to antimony is cooled, while that at which the current passes from antimony to bismuth is heated If, for example, a few drops of cold water be placed in a hollow at each of the junctions, it will be frozen at the one and warmed at the other, or if one junction be included in the bulb of an air thermometer, and the current passed first in one direction and then in the other, the heating and cooling are easily displayed

Thermo electricity is much employed as a means of measuring temperature Cumming first made use of it, and, afterwards, Nobili improved the method in 1834 (See *Thermopile*)

THERMOMETER (*θέρμη*, heat, *μετρέω*, to measure) Although literally a measurer of heat, the instrument known as the thermometer does not measure absolute quantities of heat, it serves to indicate the variations of sensible heat in two or more bodies—that is, to show whether one substance contains more or less sensible heat than another, and the relationship between such differences Thermometers are based upon the facts that heat expands substances, and that the same substance always possesses the same volume at a given temperature—that is, when it has a given amount of sensible heat associated with it, and changes its volume equally for the same change of temperature

The invention of the thermometer has been attributed to various philosophers of the seventeenth century Some have given the credit of the invention to Galileo, others to Sanctorio of Padua, Cornelius Drebbel of Alkmaer, and to Robert Fludd There seems to be every reason for the belief that Galileo and Drebbel were first acquainted with it, but whether they discovered it separately or not is uncertain It is probable that Galileo invented the air thermometer about 1602 Castelli, in writing to Ferdinand Cesarini in 1638, says, "About this time I remembered an experiment which our Signor Galileo had shown me more than thirty five years ago He took a glass bottle, about the size of a hen's egg, the neck of which was two palms long, and as narrow as a straw Having well heated the bulb in his hands, he placed its mouth in a vessel containing a little water, and, withdrawing the heat of his hand from the bulb, the water instantly rose in the neck more than a palm above the level of the water in the vessel." This, in fact, was an ordinary air-thermometer, which indicates differences of temperature by the increased or diminished volume of a mass of air enclosed in a glass bulb, communicating with a column of liquid, which ascends or descends according as the air above it contracts or expands Galileo appears to have divided the stem of his instrument into a number of divisions, but a thermometer of this nature is affected by the pressure, as well as by the temperature of the air, and, as a heat measurer, is in this form quite untrustworthy It is frequently spoken of as a *weather-glass* by old writers, for the air thermometer served the purpose both of weather-glass and thermometer from the time of its invention until the discovery

of the barometer by Torricelli, and the invention of the spirit-thermometer by the Florentine Academicians It was used by Galileo, Bacon, and many philosophers of the first half of the seventeenth century The thermometer of Drebbel was also an air thermometer The spirit-thermometer was invented by some of the members of the Accademia del Cimento in 1655 or 1656 It consisted of a glass bulb with a long stem, and was filled with alcohol, then heated so as to drive out all air from the tube, the open end of which was sealed—in fact, it was a rough form of the liquid thermometer of the present day The temperature was measured by the expansion of the alcohol, indicated by small knobs of glass stuck to the side of the tube, and forming a very rough graduation The only one we have ever seen was about 7 inches long, and of a slightly opalescent glass (possibly the result of age) The bulb was nearly an inch diameter, and the small knobs of glass affixed to the stem were rather larger than pins' heads Many of these spirit thermometers, possessing very various shapes, are figured in the "*Saggi di Naturali esperienze, fatte nell' Accademia del Cimento,*" published in 1667 The spirit thermometer of the Academy of Cimento possessed the great advantage over those of Galileo and Drebbel, that it was unaffected by the pressure of the air Edmund Halley introduced mercury in place of alcohol about the year 1680 Otto Von Guericke was the first to propose the freezing point of water as the lowest limit of the scale, while Renaldini, in 1694, proposed the boiling and freezing-points of water as the opposite limits of the thermometric scale

The instrument most used in the present day for the indication of temperature is the mercurial thermometer, the construction of which depends on the fact that mercury increases in volume under the action of heat to a much greater extent than glass If, therefore, we have a volume of mercury in a closed glass envelope, and in connection with a capillary tube, we are able to appreciate a variation of temperature by the position of the column of mercury in the tube, certain fixed positions being given and established The expansion of mercury in a thermometer tube for a certain increment of heat is obviously not the absolute expansion of the mercury for that amount of heat, but the difference between the expansion of the mercury, and the glass envelope which contains it In order to construct a mercurial thermometer, a glass bulb (usually about half an inch in diameter) is blown at one end of a capillary tube The bulb is then heated so as to expel some of the air which it contains, and the open end of the capillary tube is dipped into mercury As the air in the bulb cools, it contracts, and a certain amount of mercury is forced up into the bulb by atmospheric pressure The mercury in the bulb is now boiled, so as to expel all air from the tube, and when it is entirely full of mercury vapour, the open end is again dipped into mercury, which rises and fills both bulb and stem The bulb is next heated to a higher temperature than the thermometer is desired to indicate, which causes some of the mercury to flow from the open end of the capillary tube This end is finally sealed while the mercury in the bulb is hot by fusing the glass at the orifice As the mercury cools it contracts, leaving a portion of the capillary tube unoccupied, and this is a perfect vacuum as regards air, and contains at most but an extremely minute quantity of mercury vapour When such an instrument, having attained the surrounding atmospheric temperature is warmed, the glass bulb and the mercury within it expands, and the latter rises in the capillary tube If glass and mercury expanded equally, there would be no rise of mercury in the tube, but for an equal amount of heat mercury expands nearly twenty times more than glass, hence the thermometric indication The delicacy of the instrument—that is, the amount of ascent of the mercury in the tube for any given increment of heat—depends on the relation between the size of the bulb and the size of the capillary tube Thus, it is obvious, other things being equal, that a thermometer, with a very fine bore, will be more delicate than one with a larger bore, and that a thin flat capillary tube will be more delicate than a cylindrical tube of the same breadth

Thus far we have simply an instrument which, on being heated, will indicate that fact by the rise of mercury in a tube, and, on being cooled, will similarly show a fall of the mercury In order to acquire some idea of the degree of change of temperature, it is necessary to graduate the thermometer tube—that is, to divide it into a number of equal parts, and for this purpose it is essential that we have two fixed points or limits of temperature These are invariably the freezing and the boiling points of water To determine the former of these, the thermometer is plunged into a quantity of melting snow or ice in small pieces, and when the mercury has become perfectly stationary, a file-mark is made on the stem of the instrument at the precise height of the column of mercury If the scale of Celsius or Reaumur is employed, this will be the zero or 0°, if Fahrenheit's scale is adopted, this point will be 32°, while if the nearly obsolete scale of Delisle is adopted, this point will be 150° To determine the upper fixed point, the thermometer is placed in a chamber full of steam, which is kept well supplied by boiling water beneath it. When the mercury has become quite stationary, a file-mark is

made on the stem as before. It is to be here remarked, that the temperature of steam in contact with water varies at different pressures, and allowance must be made for this in determining the upper fixed point of a thermometer. In this country the boiling point of water, as shown by the upper division of Fahrenheit's scale, is taken as the temperature of steam in London at a pressure of 29.905 inches of mercury, reduced to the freezing point. At a pressure of 29.315 inches of mercury the temperature is 211.0°, while, if the pressure be increased to 30.444 inches of mercury, it is 212.9°. (See also *Ebullition*.)

Having now on the stem of the thermometer our two fixed points, indicating respectively the freezing and the boiling points of water, it is next necessary to graduate the instrument. The space between these fixed points has been differently divided. Delisle called the boiling point zero or 0°, and the freezing point 150°, but this scale is scarcely employed except in some parts of Russia. Reaumur called the freezing point zero and the boiling point 80°, so that he divided his instrument into 80 degrees. This thermometer is much used in Germany. A precise graduation of thermometers was first attempted by Celsius, a Swede, about the year 1741, and he took the freezing point as his zero, and the boiling point as 100; this form of scale, also called the *Centigrade*, is used throughout France, and to a great extent in other countries. It is almost invariably employed for scientific investigations in all countries. Fahrenheit proposed his scale about 1726: as the lowest attainable cold (as he imagined), he mixed pounded ice and salt, and took as the zero of his thermometer the position of the mercury column when immersed in such a mixture. He divided the space between this and the boiling point into 212 degrees, and the freezing point of water gave 32 of such divisions; thus the space between the freezing and the boiling point became 212 − 32 = 180 degrees. Fahrenheit's scale is used to a great extent in England, Holland, and North America. Any of these scales can be continued above the boiling point and below the freezing point, by equal divisions, the value of a division having been pre-determined by the distance between the two fixed points. It is obvious that every scale must be limited by the boiling and freezing points of mercury in the case of a mercurial thermometer.

It is frequently necessary to convert degrees of one thermometric scale into those of another, and this is readily effected by calculation since we have seen above that 180° Fahrenheit correspond to 100° Centigrade, or 80° Reaumur. Hence—

$$\begin{aligned}
1^\circ \text{ Fahrenheit} &= 0.55^\circ \text{ C} = 0.44^\circ \text{ R} \\
1^\circ \text{ Centigrade} &= 0.80^\circ \text{ R} = 1.80^\circ \text{ F}. \\
1^\circ \text{ Reaumur} &= 1.25^\circ \text{ C} = 2.25^\circ \text{ F}.
\end{aligned}$$

We must bear in mind, however, that the zero of the Fahrenheit scale is 32° below the freezing point of water, and this must be allowed for in the calculation. The following are the formulæ necessary for each conversion:—

Centigrade degrees	$\div 5 \times 9 + 32$	=	Fahrenheit degrees.
Reaumur ,,	$\div 4 \times 9 + 32$	=	,, ,,
Fahrenheit ,,	$-32 \div 9 \times 5$	=	Centigrade ,,
,, ,,	$-32 \div 9 \times 4$	=	Reaumur ,,
Centigrade ,,	$\div 5 \times 4$	=	,, ,,
Reaumur ,,	$\div 4 \times 5$	=	Centigrade ,,

In converting the degrees of other thermometers into degrees Fahrenheit, we must be careful to distinguish between the actual value of (say) Centigrade degrees in Fahrenheit degrees, and the value corresponding to the temperature as shown on the Fahrenheit scale. Thus, if the temperature of one room is 7° C. higher than that of another, and we desire to express this in Fahrenheit degrees, we must not employ the above formula. For $7 \div 5 \times 9 + 32 = 44.6^\circ$ F., and this gives us the number on the Fahrenheit thermometric scale corresponding to 7° on the Centigrade scale; while we require to know the value of 7° C. in degrees Fahrenheit. Now, 1° C. = 1.80° F., hence 7° C. = 7 × 1.8° F. = 12.6° F., or $7 \div 5 \times 9 = 12.6^\circ$ F., which is the difference in temperature between the two rooms expressed in degrees Fahrenheit. But if we change the form of expression, and desire to know the temperature of the air at 7° C., as shown on the Fahrenheit scale, we apply the above formula, and find it to be 44.6° F.

The following table gives the conversion of Centigrade degrees into their Reaumur and Fahrenheit representatives, for temperatures ranging between the freezing point of mercury and an approach to the melting point of tin:—

Table of Centigrade Thermometric Degrees from + 220° to — 39°, with the Corresponding Degrees according to the Scales of Reaumur and Fahrenheit

Cent	Reau	Fahr	Cent	Reau	Fahr	Cent	Reau	Fahr	Cent	Reau.	Fahr
220	176 0	428 0	155	124 0	311 0	90	72 0	194 0	25	20 0	77 0
219	175 2	426 2	154	123 2	309 2	89	71 2	192 2	24	19 2	75 2
218	174 4	424 4	153	122 4	307 4	88	70 4	190 4	23	18 4	73 4
217	173 6	422 6	152	121 6	305 6	87	69 6	188 6	22	17 6	71 6
216	172 8	420 8	151	120 8	303 8	86	68 8	186 8	21	16 8	69 8
215	172 0	419 0	150	120 0	302 0	85	68 0	185 0	20	16 0	68 0
214	171 2	417 2	149	119 2	300 2	84	67 2	183 2	19	15 2	66 2
213	170 4	415 4	148	118 4	298 4	83	66 4	181 4	18	14 4	64 4
212	169 6	413 6	147	117 6	296 6	82	65 6	179 6	17	13 6	62 6
211	168 8	411 8	146	116 8	294 8	81	64 8	177 8	16	12 8	60 8
210	168 0	410 0	145	116 0	293 0	80	64 0	176 0	15	12 0	59 0
209	167 2	408 2	144	115 2	291 2	79	63 2	174 2	14	11 2	57 2
208	166 4	406 4	143	114 4	289 4	78	62 4	172 4	13	10 4	55 4
207	165 6	404 6	142	113 6	287 6	77	61 6	170 6	12	9 6	53 6
206	164 8	402 8	141	112 8	285 8	76	60 8	168 8	11	8 8	51 8
205	164 0	401 0	140	112 0	284 0	75	60 0	167 0	10	8 0	50 0
204	163 2	399 2	139	111 2	282 2	74	59 2	165 2	9	7 2	48 2
203	162 4	397 4	138	110 4	280 4	73	58 4	163 4	8	6 4	46 4
202	161 6	395 6	137	109 6	278 6	72	57 6	161 6	7	5 6	44 6
201	160 8	393 8	136	108 8	276 8	71	56 8	159 8	6	4 8	42 8
200	160 0	392 0	135	108 0	275 0	70	56 0	158 0	5	4 0	41 0
199	159 2	390 2	134	107 2	273 2	69	55 2	156 2	4	3 2	39 2
198	158 4	388 4	133	106 4	271 4	68	54 4	154 4	3	2 4	37 4
197	157 6	386 6	132	105 6	269 6	67	53 6	152 6	2	1 6	35 6
196	156 8	384 8	131	104 8	267 8	66	52 8	150 8	1	0 8	33 8
195	156 0	383 0	130	104 0	266 0	65	52 0	149 0	0	0 0	32 0
194	155 2	381 2	129	103 2	264 2	64	51 2	147 2	—1	—0 8	30 2
193	154 4	379 4	128	102 4	262 4	63	50 4	145 4	2	1 6	28 4
192	153 6	377 6	127	101 6	260 6	62	49 6	143 6	3	2 4	26 6
191	152 8	375 8	126	100 8	258 8	61	48 8	141 8	4	3 2	24 8
190	152 0	374 0	125	100 0	257 0	60	48 0	140 0	5	4 0	23 0
189	151 2	372 2	124	99 2	255 2	59	47 2	138 2	6	4 8	21 2
188	150 4	370 4	123	98 4	253 4	58	46 4	136 4	7	5 6	19 4
187	149 6	368 6	122	97 6	251 6	57	45 6	134 6	8	6 4	17 6
186	148 8	366 8	121	96 8	249 8	56	44 8	132 8	9	7 2	15 8
185	148 0	365 0	120	96 0	248 0	55	44 0	131 0	10	8 0	14 0
184	147 2	363 2	119	95 2	246 2	54	43 2	129 2	11	8 8	12 2
183	146 4	361 4	118	94 4	244 4	53	42 4	127 4	12	9 6	10 4
182	145 6	359 6	117	93 6	242 6	52	41 6	125 6	13	10 4	8 6
181	144 8	357 8	116	92 8	240 8	51	40 8	123 8	14	11 2	6 8
180	144 0	356 0	115	92 0	239 0	50	40 0	122 0	15	12 0	5 0
179	143 2	354 2	114	91 2	237 2	49	39 2	120 2	16	12 8	3 2
178	142 4	352 4	113	90 4	235 4	48	38 4	118 4	17	13 6	1 4
177	141 6	350 6	112	89 6	233 6	47	37 6	116 6	18	14 4	—0 4
176	140 8	348 8	111	88 8	231 8	46	36 8	114 8	19	15 2	2 2
175	140 0	347 0	110	88 0	230 0	45	36 0	113 0	20	16 0	4 0
174	139 2	345 2	109	87 2	228 2	44	35 2	111 2	21	16 8	5 8
173	138 4	343 4	108	86 4	226 4	43	34 4	109 4	22	17 6	7 6
172	137 6	341 6	107	85 6	224 6	42	33 6	107 6	23	18 4	9 4
171	136 8	339 8	106	84 8	222 8	41	32 8	105 8	24	19 2	11 2
170	136 0	338 0	105	84 0	221 0	40	32 0	104 0	25	20 0	13 0
169	135 2	336 2	104	83 2	219 2	39	31 2	102 2	26	20 8	14 8
168	134 4	334 4	103	82 4	217 4	38	30 4	100 4	27	21 6	16 6
167	133 6	332 6	102	81 6	215 6	37	29 6	98 6	28	22 4	18 4
166	132 8	330 8	101	80 8	213 8	36	28 8	96 8	29	23 2	20 2
165	132 0	329 0	100	80 0	212 0	35	28 0	95 0	30	24 0	22 0
164	131 2	327 2	99	79 2	210 2	34	27 2	93 2	31	24 8	23 8
163	130 4	325 4	98	78 4	208 4	33	26 4	91 4	32	25 6	25 6
162	129 6	323 6	97	77 6	206 6	32	25 6	89 6	33	26 4	27 4
161	128 8	321 8	96	76 8	204 8	31	24 8	87 8	34	27 2	29 2
160	128 0	320 0	95	76 0	203 0	30	24 0	86 0	35	28 0	31 0
159	127 2	318 2	94	75 2	201 2	29	23 2	84 2	36	28 8	32 8
158	126 4	316 4	93	74 4	199 4	28	22 4	82 4	37	29 6	34 6
157	125 6	314 6	92	73 6	197 6	27	21 6	80 6	38	30 4	36 4
156	124 8	312 8	91	72 8	195 8	26	20 8	78 8	39	31 2	38 2

Mercury expands with great regularity between — 36° F, and 212° F, that is to say the expansion is proportional to the amount of heat received, hence the great use of this metal for thermometers Above 212°, however, the expansion is less regular, and the indications are consequently less exact. Mercury boils at 660° F, and thus effectually limits the scale in one

direction while it freezes at about $-38°$ F For lower temperatures an alcohol thermometer must be used, for alcohol has never been frozen

There are various forms of thermometers, such as the *maximum* thermometers of Rutherford, Negretti and Zambra, Phillips, &c, and the *minimum* thermometers of Rutherford, and Casella These are instruments which are self registering, and this is sometimes effected by a small index within the thermometer tube, which moves with the mercury in one direction and not in the other, and thus records the limits of its range (See also *Air thermometer*, *Differential Thermometer*, *Metallic Thermometer*, *Pyrometer*, *Thermopile*)

THERMOMETER, KINNERSLEY'S ELECTRIC An instrument used for showing the heat and repulsive force of the electric spark (See *Spark*) Its construction is the following —Into a wide upright tube two knobs project through air-tight fittings, near the bottom of the tube a smaller one opens into it, and this is turned vertically upward, and is left open at the top Both tubes are filled to the same level with water, which does not rise in the principal tube to the level of the lower ball, so that the discharge between the balls takes place through the air in the upper part of this tube As the spark passes, the air is suddenly expanded, and the water is depressed in the larger tube and thrown up in the smaller, owing to the great expansive or repulsive force exerted on the air in its neighbourhood by the spark Immediately the water falls back, the repulsion lasting only a moment, but it does not take its former level, for the air within the large tube is expanded by heat, and the water therefore depressed in that, and raised in the smaller one

THERMOMETER, SNOW HARRIS'S ELECTRIC An instrument used by the inventor for determining the heating effects of electricity in wires of different metals, but of the same length and thickness The following is a description of the instrument there are, however, several modifications of it A large glass globe is pierced with three holes, two of which are diametrically opposite to each other, and the third placed equatorially with respect to these Through the first two metal bars project to the interior, which are removeable, but which fit air-tight when in their places, and between the extremities of these is stretched a spiral of the wire to be tested A long tube is fastened on a horizontal board to which a scale is attached, and its ends are bent upwards at right angles to the tube One of these ends fits air tight into the third opening in the globe, and the other is left open Within the horizontal tube is an index of coloured sulphuric acid or mercury It will be perceived that the apparatus is simply an air thermometer with a large bulb across which the wires are stretched When the electric current or discharge is passed through the wire, it becomes heated in proportion to the resistance which it offers to the passage, the air is warmed, and expanding, drives the index along, and by the laws of expansion of gases and of specific heat, it is easy to determine what temperature the wire has been raised to The account of the instrument, and of the work done with it, are published in the *Phil Trans*, 1834

THERMO MULTIPLIER The electromotive force of a thermo electric pair being excessively small, it is necessary, in cases where it is employed for estimating small differences of temperature, to use a galvanometer which shall introduce as little resistance as possible consistent with producing a sufficient effect upon the needle Such a galvanometer goes by the name of a *thermo-multiplier* It is a common astatic galvanometer or multiplier, in which the coil of wire is short and thick About 200 turns of wire are generally used, and of a thickness not less than 0 04 of an inch

THERMOPILE An instrument much used in experiments on radiant heat, or indeed in almost any case where an extremely small difference of temperature between two points is to be determined The principle of it is given under *Thermo electricity*, and *Battery, Thermo-electric*. It consists of a series of small bars, an inch or so long, of bismuth and antimony soldered together alternately, and bent at the junction so that the bars shall be parallel, and the alternate junctions all looking in the same direction Thirty or more such bars are generally joined together, the couples being insulated laterally by slips of varnished paper, or by gypsum, and the whole forms a little cube held together by a frame of ivory, which carries two binding screws connected with the first bismuth, and the last antimony When the thermopile is used for experiments in radiant heat, it is generally placed in the axis of a double cone of copper carefully covered with lamp black to prevent radiation from external objects, and it is always used in connection with a galvanometer of small resistance called a *thermo-multiplier*

THICK PLATES, COLOURS OF When a ray of light falls upon a thick piece of glass with parallel faces, so that it is reflected both from the upper and under surface, the waves interfere and produce colour in a similar manner to that shown in the case of *thin plates* and *grooved surfaces*, which see

THIN PLATES, COLOURS OF When light falls upon an excessively thin plate of any substance, such as a soap bubble or a film of air between two glass plates, the waves of light

reflected from the upper and under surfaces interfere with each other and produce colour The colours vary with the thickness of the film, succeeding each other in a certain order called Newton's scale The colour by reflected light is always complementary to that seen by transmitted light The following thicknesses of films of air are required to produce certain colours expressed in millionths of an inch —Black (absence of colour) 0 5, blue 14·0, orange 17 2, bright red 18 33, emerald green 35 29, pale reddish white 77 00 Greater thicknesses than this cease to produce colour (See also *Newton's Scale of Colours*)

THORINUM The metallic basis of thorina A very rare earth discovered by Berzelius in 1828 Atomic weight 115 72, Symbol Th Its oxide *Thorina* (ThO) is a white powder of specific gravity 9 4 It forms a series of crystallisable salts with acids

THROTTLE-VALVE See *Governor*

THUBAN (Arabic) The star α of the constellation Draco This star was once much brighter than it is at present It has been supposed that the long sloping passage from the northern face of the great pyramid of Egypt was constructed for the purpose of watching the sub-polar meridional passages of this star, the polar star (according to this view), when the pyramid was built

THUNDER The sound which accompanies lightning It is due to the sudden disturbance of the air in the vicinity of the line in which the spark passes It is generally a long rolling sound rising and falling in intensity The duration of the thunder peal is generally attributed to re echoing of the sound produced at various places

THUNDER-ROD See *Lightning Conductor*.

TICK, MAGNETIC See *Sounds, Magnetic*

TIDES The rise and fall of the waters of the ocean twice in the course of an interval of somewhat more than one solar day, or, more exactly, corresponding in length to the interval separating the moon's successive returns to the meridian

The moon is the principal cause of the tides, the height of the wave raised by the sun's action having, to the height of the lunar wave, the proportion of about 2 to 5, so that the height of the lunisolar wave varies between the limits 7 and 3

It would be quite impossible to compress into the space at our disposal any satisfactory *resumé* of the labour of Newton, Whewell, Lubbock, Airy, and others, on the subject of the tides We refer our readers, therefore, to Airy's Treatise on Tides and Waves, *Encyc Metrop*, and the paper on the Tides by Dr Young, in the *Encyc Brit* In what follows we give merely a general sketch of two somewhat contradictory hypotheses, respecting the action of the moon in raising a tidal wave

If we conceive the case of a globe covered with an ocean of uniform depth, and that a body like the moon is *fixed* at a given distance from that globe, it is clear that the water nearest to that body, being more attracted than the globe itself, will be raised to a higher level But the globe being more attracted than the part of the water farthest from the body, that water will be *left*, so to speak, at a higher level. Thus the originally spherical shell of water will assume a prolate figure, whose longer axis passes through the moon And clearly, if the globe were slowly rotating, the axis of the prolate surface would seek continually to direct itself towards the attracting body, so that there would be high tide under that body, and at the part farthest from the body, but the real summit of the two tidal waves would always lag somewhat behind its true place

Such is one way of presenting the moon's action on the earth. It may be spoken of as the *statical* theory of tides

But, now, suppose the case of a globe, not covered as before, but with a canal full of water round its equator, rotating rapidly under the attracting body, (which suppose in the plane of the globe's equator) Then, conceiving two opposite tidal waves really to exist at any moment, and to travel round at the same rate as the globe rotates, let us consider the dynamical conditions under which these waves subsist At the summit of a wave, since the maximum elevation has been reached, water must be passing away as quickly as it is arriving The same is true also of the place of lowest water Midway between the summit of the wave, and the place of lowest water, we have on one side the place of most rapid increase of level, and on the other the place of most rapid fall At the former place, then, water must be flowing in from both sides, and at the latter water must be passing away on both sides Now if we combine all these motions we shall find that they indicate attractions corresponding to those which the moon would really be exerting if there were low water directly under her, and at a point directly opposite So that we conclude that tidal waves raised by the moon's attractions (operating precisely as though the particles of the water were so many satellites travelling round the earth under the moon's perturbing influence) would have their summits on a line nearly at right angles to (instead of nearly coincident with) that from the moon

This is the *dynamical* theory of the tidal wave. Its results are discordant with those of the statical theory. On this account it has rightly been said by Professor Nichol that the problem is not yet one for deductive science.

For further information the reader is referred to Newton's *Principia*, Lib 1, Prop 66, Cor 19; Laplace, *Mécanique Celeste*. There is an interesting paper, part of which has been summarised above, "On the Supposed Possible Effect of Friction in the Tides, in influencing the apparent acceleration of the Moon's mean motion in Longitude," by the Astronomer Royal, in the *Monthly Notices of the Royal Astronomical Society*, vol xxvi. For a full account of the actual progress of the tidal wave, the student is referred to Johnston's *Physical Atlas*.

TIMBRE. See *Colour of Tones*.

TIME. (Tempus.) A definite moment, or a definite portion of continuous duration. Under heads *Day*, *Month*, *Year*, &c., will be found an account of the various periods so named, and the methods of considering them. Under *Longitude*, the methods of determining the time at any place, compared with some fixed standard of time, are dealt with. Here we shall merely define the several modes of indicating time or time intervals.

Apparent Time is time deduced from the position of the sun upon the heavens. A truly placed sun-dial shows apparent time.

Mean Time is the time shown by a well regulated clock, constructed to indicate equal intervals corresponding to the divisions of the mean solar day.

Sidereal Time is the portion of a sidereal day elapsed since the first point of Aries last passed the meridian.

Astronomical Time is the time indicated by a clock set to mean solar time, having 24 hour divisions instead of twelve, and pointing to 24 at noon. Let it be remembered that the astronomical hours 13, 14, 15 . . . to 24, of any specified day of the month, signify the civil hours 1, 2, 3 . . . to 12 A.M. of the next day of the month. Thus 14h June 15, means 2 A.M. June 16.

TIN. A metallic element, known to the ancients under the name of Kassiteros (κασσίτερος), from the ancient name of the British Isles, the Kassiterides, where it was obtained. It sometimes occurs native, but more frequently in the form of oxide, under the name of tin stone, wood tin, stream tin, or kassiterite. In the pure state tin is a brilliant white metal of very crystalline texture, which produces a peculiar crackling noise when bent. It is permanent in the air, is very malleable, but only slightly ductile. Specific gravity 7.3. Atomic weight 118. Symbol Sn, from its Latin name *Stannum*. It melts at 237° C (459° F), and volatilises at a white heat. Owing to its permanence in the air, tin is largely used as a superficial coating for iron, in order to prevent rusting. Plates of this are known in commerce as tin plate. When tin plate or tinfoil is washed over with warm dilute aqua regia, it assumes a beautiful superficial crystalline appearance, which is sometimes used for ornamental purposes under the name of *Moirée Métallique*. The principal compounds of tin are as follows:—

Oxides of Tin. *Protoxide* (SnO in the anhydrous state). This is a bluish black crystalline powder of specific gravity 6.6. Reducing agents easily deoxidise it to metal, and oxidising agents readily convert it to stannic oxide. It forms salts which are, however, unstable.

Binoxide of Tin (SnO_2) is the principal ore of tin. It occurs native in the form of brownish-yellow translucent quadratic crystals of adamantine lustre, and specific gravity 6.3 to 7. It is easily reduced to the metallic state by ignition with reducing agents. This operation is carried out on the large scale, either in reverberatory or blast furnaces. Binoxide of tin is prepared artificially by burning tin in the air, or by acting on it with strong nitric acid. This oxide acts as an acid, and occurs in two modifications—*Stannic acid* and *Metastannic acid*. They unite with bases forming crystallisable salts, some of which are used in commerce. The most important are described under the heading *Stannates*, (which see).

Chloride of Tin. *Protoxide* or stannous chloride ($SnCl_2$) is formed when tin is dissolved in hydrochloric acid, and the product evaporated to dryness, heated in a crucible, and then distilled. It is a grayish white translucent mass, soluble in water, melting at 250° C (482° F), and boiling near redness. Its aqueous solution, when evaporated, deposits large transparent colourless crystals of hydrated chloride ($SnCl_2 \cdot 2H_2O$). It is much used in dyeing and calico printing, under the name of tin salt, and is a powerful deoxidising agent.

Stannic Chloride ($SnCl_4$), formerly called *Spiritus Fumans Libavii*, is a colourless liquid of specific gravity 2.2, strongly fuming in the air, boiling at 112° C (234° F). It unites readily with water, forming a soft buttery mass called butter of tin, which is soluble in excess of water. This salt is also used in dyeing and calico printing, under the old names of "tin solution" or "physic."

Sulphide of Tin. The disulphide (SnS_2) is prepared in soft golden yellow spangles of metallic

lustre, of specific gravity 4 6 It is known under the name of Aurum Musivum, or Mosaic Gold

TIN SALT See *Tin, Chlorides.*

TIN STONE See *Tin*

TITANIUM A metallic element discovered by Gregor in 1798, it is scarcely known in the metallic state Atomic weight 50 Symbol Ti Small cubical crystals of a copper colour and perfect metallic lustre are frequently found in the slag of blast furnaces These were for a long time considered to be metallic titanium, but Wohler (*Ann Ch Pharm* lxiii 34) has shown that they consist of mixed nitride and cyanide of titanium The principal oxide of titanium is the *di oxide* (TiO_2) This occurs native as *Rutile*, *Anatase*, and *Brookite* It is of a reddish brown colour, very hard, and of specific gravity 4 2 It much resembles silicic acid and forms a series of salts known as titanates Artificially prepared it is a white or light brown amorphous powder, insoluble in all acids A compound of titanic acid with iron is frequently met with in nature, mixed with magnetic oxide of iron, &c, under the name of *titaniferous iron sand* In some parts of the world, New Zealand for instance, it forms enormous deposits on the sea-shore It is now used in iron smelting

TOLUIDINE An artificial organic alkaloid of the composition C_7H_9N, prepared from toluol,—an oily hydro-carbon extracted from coal tar of the composition C_7H_8 Toluidine is a solid white crystalline substance, easily fusible, boiling at 205° C (401° F), and distilling unchanged It is a homologue of aniline, being the alkaloid next above it in the series It unites with acids to form salts, which are for the most part crystallisable

TONE (τονος, sound, τονοω, to sound, from the root of τεινω, to stretch L *tonus* and *tono*) An interval of music (see *Musical Interval*) Also the quality of a musical instrument or of a musical note

TOOTHED GEAR A mechanical contrivance for transmitting motion from one part of a machine to another It consists of a series of projections or teeth regularly arranged on straight cylindrical or conical surfaces termed *webs* The parts are so arranged that the teeth of one web act on those of another In order that the action may be regular it is indispensably necessary that the surfaces of the teeth should have even and regular contact, so that at every instant during the motion of the parts some points in the teeth of one part are in contact with points in the teeth of the other Moreover, the teeth should, as far as possible, roll and not slide upon one another The circle mid way between the grooves and summits of the teeth of a toothed wheel is termed the *pitch circle* The motion transmitted by the contact of the teeth is the same as would be produced by the rolling contact of the pitch circles To secure the above requirements the curves which form the outlines of the teeth are usually parts of the involute cycloid or epicycloid The thickness of the teeth varies according to the strain transmitted When both wheels are composed of the same materials the teeth are of the same size in both The intervals are a little larger than the teeth so as to allow of freer motion The *pitch* of the teeth comprises the width of the tooth and that of the interval, and is measured on the primitive or pitch circle *Spur-toothed* wheels are such as have parallel teeth lying on a cylindrical surface or web When a pair of spur wheels are in gear, their axes are parallel, and the radii of the pitch circles are proportional to the number of teeth in each When one is much smaller than the other the smaller is termed a pinion and the larger a spur wheel

A *rack* is a straight bar having teeth on one side made to gear with teeth of a right wheel, generally of small dimensions, and in this case termed a pinion When the shafts of two wheels are inclined the teeth are fixed on conical instead of cylindrical surfaces, and are then called *bevel* wheels

TOPAZ A silico fluoride of aluminium occurring in crystals Its hardness equals 8 Specific gravity 3 4 to 3 65 Lustre, vitreous, colour, yellow, white, green, or blue It is insoluble in acids, and infusible before the blow pipe When of good size and colour the topaz is used as a gem, but it is inferior in this respect to the oriental topaz. (See *Corundum*)

TOPAZ, FALSE See *Quartz*

TOPAZ, ORIENTAL See *Corundum.*

TORNADO See *Winds*

TORRICELLIAN VACUUM The space above the mercurial column in the *barometer* (*q. v*) It is not a perfect vacuum since a small quantity of the vapour of mercury is present in it.

TORRICELLI'S LAW See *Flow of Liquids*

TORRID ZONE See *Climate*

TORSION BALANCE See *Balance, Torsion*

TOTAL ECLIPSE See *Eclipse*

TOTAL REFLECTION OF LIGHT. See *Reflection of Light, Total*, and *Right Angle Prism.*

TOUCAN (The *American Bird*) One of Bayer's southern constellations The Nubecula Minor falls within this constellation It also includes an exceedingly rich cluster lying closely by the borders of the Nubecula Minor but not touching that group.

TOURMALINE, OPTICAL PROPERTIES OF The tourmaline occurs native in prismatic crystals Slices cut from this crystal parallel to the axis have the property of being transparent to light of one plane of polarisation only Slices of tourmaline are therefore largely used in researches on polarised light (See *Polarisation of Light*, *Polariser*, *Analyser*, *Polariscope*)

TOXICOLOGY (τοξικον, poison, and λογος, description.) That branch of medicine which treats of the action of poisons, or the effects of excessive doses of deleterious substances.

TRADE-WINDS See *Winds*

TRANSIT (*Transitus*, a passage) In astronomy, the passage of a heavenly body across the meridian of a place (See *Transit Instrument*) Also the passage of one celestial body across the face of another, and specially the passage of the inferior planets *Venus* and *Mercury* (*q v*) across the face of the sun

TRANSIT CIRCLE A *transit instrument* (*q v*), the telescope of which is fixed between two graduated circles, so that the altitude of a star, as well as the time of meridian passage, may be accurately noted One of the finest transit circles in existence is that which was constructed at the Greenwich Observatory in 1860, under the superintendence of the Astronomer Royal The telescope is 12 feet long, has an object-glass 8 inches in aperture The circles are 6 feet in diameter (See the works named under *Transit Instrument*)

TRANSIT EYE PIECE A transit eye piece consists of a positive eye piece, having a system of cross wires in its focus, one being horizontal, and five or seven vertical, the point of intersection between the horizontal and the central vertical wire being in the axis of the telescope By adjusting the eye piece, so that the apparent motion of a star causes the latter to travel along the horizontal wire, and recording the time it passes over each of the vertical wires, the exact moment that it crossed the axis of the instrument can be accurately calculated. (See *Transit Instrument, Eye piece, Positive Eye-piece, Micrometer Eye piece*)

TRANSIT INSTRUMENT A telescope so constructed as to point always to the meridian It rotates therefore on a horizontal axis, directed due east and west The instrument is employed to determine the moment when a star crosses the meridian As it is of the utmost importance that such observations should be made with extreme accuracy, many contrivances have been adopted to make the instrument work as perfectly as possible What is requisite is that the axis should be perfectly horizontal, that it should point due east and west, and that the optical axis of the telescope should be exactly at right angles to it The methods adopted for testing the adjustment of the telescope in these respects, will be found in Loomis's *Practical Astronomy* (a work without which no astronomical library can be regarded as complete), and Pearson's *Introduction to Practical Astronomy*

In observing a transit, the passage of the star across successive vertical lines in the telescopic field of view (fine silk threads, or else threads from a spider's web are employed), is carefully timed in accordance with the beats of a pendulum vibrating in sidereal seconds

TRANSITION TINT A peculiar tint produced when a plate of quartz 3 75 mm thick is viewed in the polariscope The colour is a pale purple, and it changes very rapidly to red or violet, according as the analyser is turned one way or the other It is frequently made use of in measuring the angle of rotation in liquids which polarise circularly (See *Circular Polarisation of Liquids*)

TRANSMISSIBILITY OF FORCES (*Transmittere*, from *trans*, over or across, and *mittere*, to send) A principle in mechanics, which states that a force may be applied at any point in the line of its direction, provided this point be connected with the first point of application by a rigid and inextensible straight line For example, if a weight be attached by a cord to a spring-balance, the effect will be the same at whatever point in the cord the weight is tied Similarly, a force may be applied to a body, either directly, or by the interposition of a rigid rod, and, supposing the rod to be supported independently, the result will be the same Again, if equal forces are supposed to be acting in opposite directions at the extremities of a string, the string will be in equilibrium, and if we take any point in the string, not an extremity, and transfer one of the forces to it, the forces will be still in equilibrium Hence we may consider the force applied at one end to be transmitted through the string, and we may suppose two opposite forces at any point equal to the forces at the extremities Either of these is termed the *tension* of the string Suppose the string to pass round a smooth peg, ring, or surface, in this case also the tension of the string is the same at every point

TRANSMUTATION OF ENERGY. (*Trans*, and *muto*, to change) The principle that any one of the various forms of physical energy can be converted into each of the others The laws of the transmutation have been definitely ascertained, and perfectly demonstrated in many

cases, and the change in form has been traced in so many others, as to lead to an irresistible inference that one form of energy cannot originate otherwise than by devolution from pre-existing energy We will take in illustration the order of classification explained under Energy. (See *Energy*)

Relation of the Kinetic and Potential Energies of Visible Motion When a stone is thrown vertically upwards with a certain velocity, there is given to it at the instant of starting, an energy, which is measured in foot-pounds by multiplying its weight by the square of its velocity, and dividing the product by twice the velocity acquired by a falling body in a second of time. Hence the energy of a moving body, or the quantity of work it can perform, varies as the square of its velocity As the velocity diminishes, therefore, the amount of actual energy diminishes, but the advantage due to position increases at the same rate

For instance, if a body weighing 1 lb be projected with a velocity which would carry it vertically to a height of 100 feet, when it starts there will be 100 units of work in it, when it has passed through 60 feet there will be only 40 units of work accumulated in it But the body being 60 feet higher than before, will have gained an advantage of position, represented by 60 units, thus 60 units of kinetic energy have been changed to potential energy, and at any instant of its flight its kinetic energy + its potential energy will be equal to the whole energy with which it started

Visible Kinetic Energy and Heat Kinetic energy of motion may be transformed into heat On the stone's falling its potential energy becomes kinetic When it strikes the ground the kinetic energy is again transformed It is not annihilated, but has become energy of heat It has long been known that the actual energy of a moving body may be changed into the molecular energy of heat Pieces of dry wood when rubbed together will become so hot as to ignite, the boring tools of a carpenter become hot by being used, when a piece of metal is rubbed vigorously on a rough surface it becomes too hot to hold Again, when a train in motion is brought to a stand still by applying a brake, the rails become hot, and sparks are seen to fly from the wheels Bullets shot at a target frequently show signs of fusion after impact In all these cases the energy of visible motion is transmuted into heat The amount of the one form of energy which will produce a given amount of the other, has been calculated by Joule and others (See *Mechanical Equivalent of Heat*) If a weight of 1 lb be raised to a height of 772 feet, and be let fall, on striking the ground it will generate as much heat as will raise 1 lb of water 1° F

Reversibility of Energy By means of a conception of Carnot, a principle, which may be termed the reversibility of energy, has been established If a certain amount A of one form of energy produce an amount B of another form, then B is the quantity of the latter which is required for the production of an amount A of the former If 772 foot pounds of work must be expended to raise a pound of water 1°, then the heat which must leave a pound of water in order that its temperature may be reduced 1°, is capable of performing work equivalent to 772 foot-pounds In the steam engine, the heat of the burning coal is changed to energy of motion, and this is again transformed to heat By Carnot's principle, if an engine by consuming a certain amount of heat does a given quantity of work, by the consumption of a similar amount of work it would restore to the source the quantity of heat taken from it

Visible Kinetic Energy and Electricity Visible kinetic energy is changed into the kinetic energy of electricity by a magneto electric-machine, and into potential energy of electricity, when a sheet of glass is made to revolve against a surface of silk Again, the actual energy of electricity is transformed into the energy of visible motion when a piece of iron is drawn to the poles of an electro magnet, when two wires conveying electric currents attract one another, or when a current is made to pass through a wire which is near a magnetic needle, and the needle is in consequence forcibly deflected by the current

Electricity and Heat Suppose the strength of a current of electricity passing along a wire to be measured by its power to deflect a magnetic needle Suppose the wire to be of copper, and the amount of deflection noted, and then let the copper be replaced by platinum, which offers a greater resistance to the current It will be found that the wire becomes hot, and that the needle is deflected through a smaller angle Energy of heat is here produced at the expense of the energy of electricity in motion With powerful batteries all metals are fused, even iridium and platinum, which are the least fusible A battery of 30 or 40 Bunsen's cells will volatilise fine wires of lead, tin, zinc, copper, gold, and silver (See *Current, Heating Effects of*)

When a bar of antimony and a bar of bismuth are soldered together at one extremity, and the free ends united by a copper wire, on the application of heat a current of electricity is found to circulate through the wire, and the strength of the current is an exact and delicate measure of the heat applied (See *Thermo-electric Pile*) When a crystal of tourmaline changes temperature, its extremities assume opposite electric states, thus affording an example of the change of heat

into the potential energy of electric separation The Voltaic arc is a brilliant example of the conversion of electricity into the actual energy of radiant heat and light

Chemical Action and Heat The energy of chemical action or chemical separation and heat, are mutually convertible A given amount of chemical action produces a definite amount of heat, and this same quantity of heat is required to reverse the chemical changes which have produced it It is difficult to determine accurately the amount of heat equivalent to a given amount of chemical action, chiefly because it is very difficult to confine the transformation of energy to these two forms only, nevertheless, the relation between the amount of heat evolved and the quantity of chemical action has been determined by several eminent physicists, and the differences of the results of the latest experiments lie within comparatively small limits For example, Rumford calculated that 1 gramme of charcoal in combining with $2\frac{2}{3}$ grammes of oxygen to make carbonic acid, would evolve heat sufficient to raise the temperature of 8000 grammes of water 1° C Andrews made the quantity 7900 grammes, and Favre and Silbermann 8080 grammes Hence the true quantity must be near 8000 grammes One gramme of hydrogen in combining with 8 grammes of oxygen to form water, evolves heat sufficient to raise about 34,000 grammes of water 1° C (Andrews, 33,881, Favre, 34,462) Similarly, the quantities of heat evolved in the combustion of other elements have been found with equal precision (See *Heat of Chemical Combination*)

Chemical Action and Electricity The chemical action going on in a Voltaic battery produces electricity What becomes of the energy of electricity which is constantly generated so long as the chemical action continues? The experiments of M Favre have completely answered this question Just as a definite amount of carbon, by its union with oxygen, produces a determined quantity of heat, so the consumption of a definite amount of zinc in the battery produces a definite quantity of electricity which in its turn gives rise to an invariable amount of heat When the poles of the battery are connected by a very good conductor such as a short thick wire, the heat produced is confined to the battery itself, but when a less perfect conductor is used heat manifests itself in the conductor In this case part of the heat is in the wire and part in the battery, but the whole amount of heat produced in all the parts of the circuit by the consumption of a given quantity of zinc is the same in this case as in the other If the electric current be used to do other work, a corresponding amount of heat is withdrawn from the battery

Suppose two tubes of glass, closed at one end, to have pieces of platinum wire fused into the closed ends, and to be filled with water and placed with the open ends under water in the same vessel Let the poles of a battery be connected with the platinum wires The water will be decomposed, oxygen collecting in one tube and hydrogen in the other The amount of gas set free in a given time will be proportional to the strength of the current If the battery be taken away, and the ends of platinum be connected by a copper wire the gas will soon disappear, and while it is passing into water a current will be found to circulate the wire in a direction opposite to that which produced the decomposition Here then electricity in motion produces energy of chemical separation, and the latter again reproduces the former

Dissipation of Energy Although we may definitely estimate the exact equivalents of the various forms of energy we are not always able perfectly to reverse a given transmutation For instance a given quantity of mechanical work will produce an equivalent amount of heat, and if all of this heat could be changed into mechanical work the original amount would be produced, but we are never able to reconvert all the heat into work (see *Heat Engine*) Energy which cannot be reconverted to its previous form is said to be *dissipated* Dissipation of energy is constantly going on throughout the universe Thus, the energy of the sun's rays produce streams of water, winds, and currents By its action on plants it separates carbon from oxygen, a process which is reversed when wood is ignited The moon and the sun give rise to tidal energy *Through all these channels energy is being constantly dissipated*

Taking, therefore, the forms of energy as classified under the article energy, we find that kinetic energy of visible motion may be traced into visible potential energy, heat actual and potential, and electricity Visible potential energy may become actual or kinetic, and through this may pass into the other forms Electricity, kinetic and potential, may be transformed into energy of visible motion, into heat or light, and into chemical action, or the potential energy of chemical separation, and all these again may reproduce electricity Heat may produce visible motion, electricity, or chemical action, so that, either mediately or immediately, each form may produce any of the others Actual energy, of all forms, may be transformed into potential energy, and may remain in this state for an indefinite period of time The energy of heat, which is derived from the combustion of coal, was originally derived from radiant heat and light received from the sun, but has been remaining in store for ages

Sir John Herschel wrote the following remarkable passage on the transformations of this solar force —

"The sun's rays are the ultimate source of almost every motion which takes place on the surface of the earth By its heat are produced all winds, and those disturbances in the electric equilibrium of the atmosphere which give rise to the phenomena of lightning, and, probably, also to terrestrial magnetism and the aurora By their vivifying action vegetables are enabled to draw support from inorganic matter, and become, in their turn, the support of animals and man, and the source of those great deposits of dynamical efficiency which are laid up for human use in our coal strata By them the waters of the sea are made to circulate in vapour through the air, and irrigate the land, producing springs and rivers By them are produced all disturbances of the chemical equilibrium of the elements of nature, which by a series of compositions and decompositions give rise to new products and originate a transfer of materials Even the slow degradation of the solid constituents of the surface, in which its chief geological change consists, is almost entirely due, on the one hand, to the abrasion of wind or rain and the alternation of heat and frost, on the other, to the continual beating of sea waves agitated by winds, the results of solar radiation Tidal action (itself partly due to the sun's agency), exercises here a comparatively slight influence The effect of oceanic currents (mainly originating in that influence), though slight in abrasion, is powerful in diffusing and transforming the matter abraded, and, when we consider the immense transfer of matter so produced, the increase of pressure over large spaces in the bed of the ocean, and diminution over corresponding portions of land, we are not at loss to perceive how the elastic force of subterranean fires, thus repressed on the one hand and released on the other, may break forth in points where the resistance is barely adequate to their retention, and thus bring the phenomena of even volcanic activity under the general law of solar influence"

We have seen that there can neither be creation nor annihilation of energy so that the total amount in the universe is constant The establishment of this general law has suggested the inquiry into the origin of the sun's energy Theories of combustion have been propounded, but it has been clearly shown by Sir W Thomson that chemical combination is inadequate to produce the solar heat Mr Waterston proposed a theory which has found considerable favour, and is usually termed the meteoric theory He considered that the existence of the masses of matter which are known to be moving through space together with the law of gravitation is quite sufficient for the production of the heat of the sun It is highly probable that meteoric masses of matter frequently come into collision with the sun, and that then mechanical force is, in consequence, converted into heat, but there is nothing to show that the shower of meteors is such as would restore to the sun all the heat which he gives out Indeed, from what we are able to see of the dissipation of energy and the operation of the principle of degradation throughout the universe, there is reason to believe that the sun emits more heat than he receives and that only a sufficient length of time is required for the complete dissipation of the solar energy

TRANSMUTATION OF RAYS A term introduced by Professor Challis in 1865 (*Phil Mag*, p 36), to express the alteration which rays undergo when they are submitted to certain actions In Professor Stokes' experiments on fluorescence, the ultra violet rays of the spectrum, which possess great refrangibility, and are incompetent to excite vision because their rapidity of vibration is greater than that of any visible rays, have their velocity reduced, and their refrangibility lowered, when they at once become visible So also in Professor Tyndall's experiments on calorescence, the ultra red rays of the spectrum which possess low refrangibility, and are caused by vibrations which are too slow to excite the sense of vision, have their refrangibility raised and their velocity increased, and then become visible In both instances invisible rays are transmuted into visible rays (See *Fluorescence; Calorescence, Obscure Heat*)

TRANSPARENCY (*Trans*, through, and *pareo*, to appear) That property of a body which allows rays of light to pass through it It is the opposite to opacity, and like this term is sometimes extended to the whole spectrum Thus we speak of a solution of iodine in bisulphide of carbon as being transparent to heat, and of rock crystal as being transparent to the actinic rays

TRANSVERSE MAGNET A name given to bars magnetised in a direction at right angles to their length, so that they have their poles at their sides instead of at their ends

TRAVELLING BAROMETER See *Barometer*

TREVELYAN'S EXPERIMENT In 1805 a curious observation was made in some smelting works in Saxony. A mass of hot silver had been placed upon an anvil to cool, and while cooling a peculiar humming sound was heard to proceed from the silver, which was in a state of rapid reciprocal motion. In 1829 Mr. Arthur Trevelyan by chance laid a hot soldering-

iron upon a mass of lead, and here, as in the case of the silver, a sound was heard, and the soldering iron was observed to be in oscillation This led Mr Trevelyan to make a number of experiments on the subject, with a view of ascertaining the cause of the sound, and the best means of producing it, and he devised an instrument for the purpose which is known as "*Trevelyan's Instrument*" It consists of a thick piece of brass about four inches long by two inches wide, and of a varying thickness in the same instrument of from three quarters of an inch at the thickest portion to one quarter or less at the edges In form it is sometimes triangular, sometimes oblong, with one of its broad sides convex Lengthwise there is a groove in the convex side of the brass, and a bar of metal about a foot long is connected with the brass to serve as a handle for convenience in removing it from the fire The grooved piece of brass is called the *rocker*, and is the representative of the silver ingot, and of the soldering iron, in the original experiments It is heated to a temperature of 300° or 400° F, and is then placed so that the grooved surface rests upon a block of lead It immediately enters into vibration, and a clear musical note is heard, which may be varied in pitch by weighting the rocker, most conveniently by slight pressure, as with the point of a pencil Sometimes the rocker consists of a convex piece of brass without a groove, which is placed upon a ring of lead deeply grooved beneath the brass rocker In either case, there are two different metals in contact by means of two sharp edges, and the cause of the musical note produced, is the same It is caused by the sudden expansion by heat of the cold metal with which the hot rocker is in contact At the point of contact a small bump is raised on the lead by the heat of the rocker, and this tilts up the rocker, and causes another portion of it to come in contact with the lead on the other edge of the groove, a second bump now rises, and throws back the rocker to the other side, and so on These reciprocal motions follow each other with sufficient rapidity to produce a musical note Of course, the amplitude of oscillation of the rocker is exceedingly small, to the eye the motion is scarcely apparent, but when a mirror is attached to the upper surface, and a beam of light reflected therefrom to a distance, this long index enables the vibratory motion to be distinctly followed *Gore's rolling balls* are instances of the same effect A light metal ball is placed between two metal rails, and serves to connect them, and by this means to close the circuit of a voltaic battery, with the opposite poles of which they are connected At the contact of the ball with the rails, the electric current suffers a greater resistance than when passing through the continuous metals, hence heat is developed, the portion of the rail immediately beneath the ball is raised, and the ball moves This action is obviously analogous to that which causes the movement of the rocker in Trevelyan's experiment

Commenting on the production of motion and of sound in the Trevelyan experiment, Tyndall says —"Looked at with reference to the connection of natural forces, this experiment is interesting The atoms of bodies must be regarded as all but infinitely numerous The augmentation of the amplitude of any oscillating atom by the communication of heat is insensible, but the summation of an almost infinite number of such augmentations becomes sensible Such a summation, effected almost in an instant, produces a ripple, and tilts the heavy mass of the rocker Here we have a direct conversion of heat into common mechanical motion But the tilted rocker falls again by gravity, and in its collision with the block, restores almost the precise amount of heat which was consumed in lifting it Here we have the direct conversion of common gravitating force into heat Again, the rocker is surrounded by a medium capable of being set in motion The air of this room weighs some tons, and every particle of it is shaken by the rocker, and every tympanic membrane, and every auditory nerve present is similarly shaken Thus we have *the conversion of a portion of the heat into sound* And, finally, every sonorous vibration which speeds through the air of this room, and wastes itself upon the walls, seats, and cushions, is converted into the form with which the cycle of actions commenced, namely, into heat"

TRIALKALAMIDES See *Amides*.

TRIAMIDES See *Amides*

TRIAMINES See *Amides*

TRIANGLE OF FORCES This principle is thus enunciated —When three forces acting on a particle can be represented in magnitude and direction by the three sides of a triangle taken in order, they will be in equilibrium This is an easy deduction from the parallelogram of forces (see *Composition of Forces*), for if we obtain a parallelogram, of which two adjacent sides represent two of the forces, and the diagonal their resultant, we can see that a force equal and opposite to the resultant will keep the system in equilibrium This is the precise effect given by taking the sides of the triangle in order Thus the forces represented by the sides of the triangle A B C, act in a direction respectively from A to B, from B to C, and from C to A If one be reversed, they no longer represent forces in equilibrium The directions of the forces are supposed to pass through a point, and the sides of the triangle to be parallel to them.

The converse of this proposition is also true When three forces, acting on a particle, are in equilibrium, the sides of any triangle which are parallel to the lines of action of the forces are also proportional to the forces Again, applying the geometrical principle that, if there be two triangles, such that the sides of one are respectively perpendicular to those of the other, then these sides are proportional, we can further add to the above proposition, that if lines be drawn perpendicular to the direction of the forces, they will be proportional to the forces

From the triangle of forces it follows that, when three forces, acting on a point, and in different directions, are in equilibrium, the sum of any two is greater than the third The only case where the sum of any two forces may be equal to the third is when the triangle vanishes, and the forces all act in the same straight line the first two being opposite in direction to the third Again, if three forces in the same plane, not parallel, are in equilibrium, their directions pass through the same point For if two meet in a point, they may be replaced by their resultant, and in order that this resultant may be in equilibrium with the third force, they must act in the same straight line, and, consequently, the line of action of the third force must pass through the intersection of the first two

TRIANGULA (The triangles) Triangulum Boreale, or the northern triangle, formed one of Ptolemy's constellations Hevelius with his accustomed ingenuity in devising useless additions to the celestial sphere formed the constellation Triangulum Minus The two triangles are now conveniently included in one asterism under the name Triangula

TRIANGULUM (Abbreviated from *Triangulum Australe*, the Southern Triangle) One of Ptolemy's southern constellations It contains several conspicuous stars, and is an altogether finer constellation than the northern triangle

TRIATOMIC ALCOHOLS See *Alcohols, Series of*

TRICHROISM See *Dichroism*

TRIETHYL PHOSPHINE An organic phosphorus base (see *Phosphorus Bases*) formed from phosphuretted hydrogen, by replacing the three equivalents of hydrogen by ethyl Its composition is $(C_2H_5)_3P$ It is a transparent colourless liquid, of specific gravity 0.812 It boils at 127.5° C (261.5° F) Its odour resembles that of the hyacinth It unites with acids, &c Its most remarkable characteristic is the delicacy of its reaction with disulphide of carbon. When the vapour of this compound is allowed to fall upon a solution of triethyl phosphine in a watch glass it soon becomes covered with beautiful red crystals, having the composition $2(C_2H_5)_3P\ CS_2$ So delicate is this test, that a solution of triethyl phosphine in alcohol may be used to detect the presence of disulphide of carbon in coal gas, very few samples of which, when allowed to bubble through the solution for ten minutes, fail to show a red colour

TRIPLET A simple form of microscope similar to Wollaston's *Doublet*, but having a third lens, double convex, and of short focus placed between the two plano convex lenses

TROMPE (Fr *trombe*, a trumpet, a waterspout) An arrangement for producing a blast by means of a stream of water falling through a tube It was invented about the middle of the seventeenth century The earliest account of the invention is in a work by Father Jean François, published in 1655, in which there is a section entitled "Du Meslange des Eaux avec l Air, et d'une invention pour exciter un vent impetueux " Several modifications of the trompe have been constructed since its first invention, the main difference consisting in the way in which air is allowed to enter the tube The modern trompe consists of a large cistern, in which there is a constant depth of from 4 to 6 feet of water From the bottom of the cistern proceed two tubes from 20 to 30 feet long, the lower extremities of which pass into a wooden wind-chest, furnished with an arrangement for keeping the water at a certain level, so that no air can escape except by a blast pipe in the upper part of the chest Beneath the lower extremity of each tube there is a flat iron plate to break the fall of the descending water The upper part of each tube is contracted at the point where it joins the cistern, and immediately beneath the contracted part four holes are made in the circumference of the tube When water is allowed to flow from the cistern into the air chest, a quantity of air is carried down with it, and a perfectly regular and constant current of air issues from the blast pipe For the history of the trompe, explanations of the cause of the descent of air in different modifications of the instrument, and an account of the most favourable conditions under which air is carried down by a stream of water, see Mr G F Rodwell's paper in the *Philosophical Magazine* for Sept 1864

TROPICAL YEAR See *Year*

TROPICS (τροπη, a turning about) In astronomy, the parallels of declination through the sun's solstices (See *Cancer*, and *Capricornus*)

TUNGSTEN A metallic element scarcely known in the pure state, but it appears to be very hard and infusible, and of an iron grey colour Specific gravity 17 to 18 Atomic weight 184 Symbol W (from Wolfram) The only compound which need be noticed is the ***trioxide of tungsten*** (WO_3) This is a lemon yellow powder of specific gravity 5.27 It unites

with bases to form salts called tungstates Of these the sodium salt ($Na_2O\,WO_3$) is of some importance as a mordant in dyeing and calico printing, and it has also been proposed for rendering textile fabrics uninflammable

TURACINE An animal pigment discovered by Professor Church in the primary and secondary pinion feathers of four species of Touraco or Plantain eater It contains 5 9 per cent of copper which cannot be removed without the destruction of the colouring matter itself The spectrum of Turacine shows two black absorption bands (See *Phil Trans* 1869)

TURBINE (*Turbo*, anything which revolves) A horizontal water wheel, with inclined vanes attached to the spokes, so as to form portions of the surface of a screw, like the sails of a windmill A stream of water descends on the wheel, passes through it, and causes it to revolve

In 1849 Mr Ruthven patented a turbine screw for steam ships, which has been tried with some success in the iron-clad gun boat Waterwitch (See also *Water wheels*)

TURBITH MINERAL See *Sulphates*, *Mercury*

TURPENTINE, OIL OF A volatile spirit of the composition ($C_{10}H_{16}$), extracted by distillation from the viscid resin exuding from coniferous trees Its specific gravity is about 0 86, and its boiling point about 170° C (338 F), but this varies in different samples It is a colourless mobile liquid of a peculiar strong odour, insoluble in water, and much used as a solvent for many gums and resins

TWILIGHT The light which continues after the sun has set It is due to the fact that the sun illuminates part of the atmosphere above the horizon plane of the observer, some time after he has set Under the head *Atmosphere* will be found some remarks on the height of the atmosphere as deduced from the duration of twilight It is usually considered that twilight lasts until the sun is about 18° below the horizon Twilight, therefore, lasts longer in high than in low latitudes, because in the former the sun's path is inclined at a smaller angle to the horizon, so that he has to traverse a longer arc before his vertical depression below the horizon is so much as 18° In summer, in latitudes higher than 48½°, there is no real night, because the sun's midnight depression below the horizon being in spring the complement of the latitude, and in summer 23½ degrees less, is for such latitudes less at midsummer than 18°

TYCHONIC SYSTEM The system by which Tycho Brahe endeavoured to account for the motions of the sun, moon, and planets He supposed that all the planets circle round the sun but that the sun and moon circle round the earth

TYPES, MULTIPLE AND MIXED According to Dr Odling —

H_2Cl_2 H_4O_2 H_6N_2	Dichloride Dihydrate Diamide	$S''Cl_2$ — —	$Zn''Cl_2$ $Zn''H_2O_2$ $Zn''H_4N_2$	$Etn''Cl_2$ $Etn''H_2O_2$ $Etn''H_4N_2$
H_3Cl_3 H_6O_3 H_9N_3	Trichloride Trihydrate Triamide	$B'''Cl_3$ $B'''H_3O_3$ $B'''H_6N_3$	$Sb'''Cl_3$ $Sb'''H_3O_3$ $Sb'''H_6N_3$	$Gly'''Cl_3$ $Gly'''H_3O_3$ $Gly'''H_6N_3$
$\left\{\begin{matrix} HCl \\ H_2O \end{matrix}\right.$ $\left\{\begin{matrix} HCl \\ H_3N \end{matrix}\right.$ $\left\{\begin{matrix} H_3N \\ H_2O \end{matrix}\right.$	Chlorid hydrate Chlorid amide Hydrat amide	$\left.\begin{matrix} (SO_2)'' \\ H \end{matrix}\right\} \begin{matrix} Cl \\ O \end{matrix}$	$\left.\begin{matrix} (SO_2)'' \\ H_2 \end{matrix}\right\} \begin{matrix} Cl \\ N \end{matrix}$	$\left.\begin{matrix} (SO_2)'' \\ H_3 \end{matrix}\right\} \begin{matrix} N \\ O \end{matrix}$

TYPHOON. See *Winds*.

U

ULMIC ACID See *Humic Acid*

ULMIN ACID See *Humic Acid*

ULTRA RED-RAYS See *Obscure Heat*, *Calorescence*.

ULTRA-VIOLET RAYS See *Actinism*

UMBRA See *Eclipse and Penumbra*

UNANNEALED GLASS, DOUBLE REFRACTION OF. Pieces of unannealed glass cut and polished to the shape of cubes, discs, triangles, &c , are frequently used for exhibiting the phenomena of coloured polarisation The state of tension in which the particles are kept

renders the glass double refracting, and when examined in the polariscope a brilliant coloured pattern and a black or white cross are seen (See *Polarisation of Light*)

UNDULATORY THEORY OF LIGHT The theory of light generally adopted at the present day It pre-supposes the existence of a universal ethereal medium infinitely elastic and subtle pervading all space The sensation of light is occasioned by rapid oscillations, vibrations, or waves in this imponderable ether A luminous body, a candle, for instance, is supposed to be capable of exciting these vibrations, which are thence transmitted in all directions in straight lines with a velocity of about 192,000 miles per second The analogy which exists between the phenomena of light and sound, as well as the remarkable concordance between the observed phenomena of light and those predicted by mathematical investigation, render it in the highest degree probable that the undulatory theory of light is very near the true one

Sir John Herschel gives the following table of the number of waves comprised within the space of an inch, constituting differently coloured lights, also the number of each which strike upon an object, the eye for instance, in one second of time —

Colours of the Spectrum	Number of Undulations in an inch	Number of Undulations in a second
Extreme red,	37640	458,000000,000000
Red,	39180	477,000000,000000
Intermediate,	40720	495,000000,000000
Orange,	41610	506,000000,000000
Intermediate,	42510	517,000000,000000
Yellow,	44000	535,000000,000000
Intermediate,	45600	555,000000,000000
Green,	47460	577,000000,000000
Intermediate,	49320	600,000000,000000
Blue,	51110	622,000000,000000
Intermediate,	52910	644,000000,000000
Indigo,	54070	658,000000,000000
Intermediate,	55240	672,000000,000000
Violet,	57490	699 000000,000000
Extreme violet,	59750	727,000000,000000

UNIAXIAL CRYSTALS See *Crystals, Optic Axis of*

UNISON (*Unus*, one, and *sonus*, sound) In music an accordance or coincidence of sounds proceeding from an equality in the number of vibrations per second of the bodies producing them, as in the notes produced by two strings of the same length, thickness, and tension

UNIT MAGNETIC POLE *Definition* A unit magnetic pole when placed at unit of distance from an equal and similar pole repels it with unit of force

In electrical and magnetic measurements the metrical system of length, mass, &c, are now employed by the most accurate writers, and by the best electricians According to this system the particularised definition of a unit magnetic pole stands thus —a unit magnetic pole when placed at a distance of one centimetre (0 3937 inches) from an equal and similar pole repels it with a force, which if applied to a mass of one gramme (15 43 grains) for one second would generate in it a velocity of one centimetre per second

UNIT OF HEAT As thermometers, (although literally *measurers*), only indicate relative quantities of heat, it is necessary in all cases in which we desire to measure an absolute amount of heat, to adopt some definite and fixed quantity, some standard or unit in terms of which we can express any other quantities we may desire to notify The unit of heat generally adopted in this country is the amount of heat competent to raise one pound of water through 1° of Fahrenheit's scale The weight is avoirdupois, and the water is weighed in vacuo at a temperature between 55° and 60° F Sometimes the quantity of heat necessary to raise 1 lb of water from 0° to 1° Centigrade is taken as a unit, while on the continent the unit or *calorie* is the quantity of heat necessary to raise 1 kilogramme of water from 0° to 1° C The former of these is readily converted into the latter, for 1 calorie is equal to 2 2 of the unit in which 1 lb and 1° C are the terms, while this latter is equal to 0 45 calorie

UNITS, ELECTRICAL The units now generally employed in electrical measurements are those decided on by the committee appointed by the British Association for the Advancement of Science, to consider the standards of electrical resistance It appeared to the committee that the only system consistent with our present knowledge of the relations existing between electrical, magnetic, thermal, and chemical, phenomena, and of their connection with the fundamental units of time, space, and mass, is that known as the "absolute" system, in which the units employed are directly derived from those fundamental units. There are four

electrical elements capable of measurement, strength of the current, electro-motive force, resistance, and quantity; and, taking into consideration the work done by the current, the units are defined so as to satisfy the following relations which have been shown to be possible by the researches of Weber, Thomson, and Helmholtz "The unit current conveys a unit quantity of electricity through the circuit in a unit of time The unit current in a conductor of unit resistance, produces an effect equivalent to the unit of work in the unit of time The unit current will be produced in a circuit of unit resistance by the unit electro-motive force" There is one more condition added, which is one or other of the following "The unit current, flowing through a conductor of unit length, will exert the unit force on a unit magnetic pole at a unit distance," or "the unit quantity of electricity will repel a similar quantity at the unit distance with a unit force" Each of these, satisfying also one or other of the last conditions is a consistent system; one is founded on the estimation of electric quantities by electro-magnetic, the other by electrostatic effects When the unit of electric resistance is decided on, the magnitudes of the units in the two systems are determined These magnitudes are not the same, but they bear to each other a fixed relation which has been determined The following is the way in which the unit of resistance is defined —

When a wire is moved across the lines of magnetic force a current is generated in it whose strength, other things remaining the same, is proportional to the number of lines cut in a given time Suppose that a rod one metre long were caused to slide upon two conducting rails in connection with the earth, placed in such a position that the rod in its motion upon the rails cuts the horizontal lines of the earth's magnetic force at right angles, and let the whole resistance of the circuit thus formed be by some means kept constant for every position of the slider If the slider be moved along with a fixed velocity a current whose strength depends upon the electric resistance in the circuit will be generated Hence also the resistance of a circuit is proportional to the velocity with which a slider of unit length must move across a magnetic field of unit intensity in order to generate a unit current in the circuit The unit of electric resistance, then, is defined to be that in which a slider of one metre length moving with a velocity of 10×10^6 (ten million) metres per second across the line of force in a magnetic field of unit intensity would generate unit current

To perform the experiment just indicated would be scarcely possible, but by a method suggested by Thomson, and used experimentally by Messrs Maxwell, Balfour Stewart, and Jenkin, the resistance of various wires have been determined in terms of this absolute unit of resistance, and coils have been constructed whose resistance in terms of it is accurately known and copies of the absolute unit carefully constructed by comparison with them are furnished through the British Association

For further details on this subject, and for the proof of the fundamental propositions which we have referred to above, the reader may consult the reports of the committee to the British Association from year to year since 1862, and especially that of 1863, of which the above is a very brief abstract

The following table gives a comparison of the various units that have been proposed for measuring electrical resistances, in terms of the British Association, or absolute unit, the ohmad as it is sometimes called —

	B A Units
B A unit or ohmad A velocity of 10^7 metres per second,	1 00
Absolute $\frac{\text{foot}}{\text{second}} \times 10^7$ electro magnetic units (new determination),	0 3048
Thomson's unit Absolute $\frac{\text{foot}}{\text{second}} \times 10^7$ electro magnetic units (old determination),	0 3202
Jacobi's unit 25 feet of a certain copper wire weighing 345 grains,	0 6367
Weber's unit Absolute $\frac{\text{metre}}{\text{second}} \times 10^7$ electro-magnetic units (1862),	0 9191
Siemens' unit One metre of pure mercury One square millimetre section at 0° C (1864 issue),	0 9563
Digney's unit 1 kilometre of iron wire, 4 mm. in diameter. Temperature not known,	9 266
Varley's unit One standard English mile of one special copper wire $\frac{1}{16}$ in diameter,	25 61
Matthiessen's unit One standard English mile of pure annealed copper wire $\frac{1}{16}$ in diameter, at 15° 5 C,	13 59

UNUKALHAI (Arabic) The star α of the constellation Taurus

UPWARD PRESSURE OF LIQUIDS If a cylinder open at both ends be immersed in a vertical position in a liquid, with its upper end above the liquid's surface, the equilibrium of the liquid will not be disturbed, nor will any change take place if the lower end be closed by a thin plate That plate, however, must be pressed downwards by the weight of the cylindrical column of water above it, therefore it must be pressed upwards by an equal force If, when the plate is on the bottom of the cylinder the liquid in the cylinder is withdrawn, one of these counteracting forces is removed, and the remaining or upward force presses the plate on to the cylinder with a force equal to the weight of the liquid which was in the cylinder Or in general terms, the upward pressure on the bottom of a horizontal surface immersed in a liquid is equal to the weight of a column of liquid having that surface for a base, and the vertical distance of immersion for a height The loss of weight which a body experiences when plunged into a liquid may be deduced from this consideration If a solid circular cylinder, with horizontal ends, be immersed in a liquid, every unit of superficial area will receive pressure proportional to its depth (See *Lateral Pressure*) It is clear that for every horizontal pressure acting on a unit of surface on the round sides of the cylinder, there is an equal and opposite one on the other side of the cylinder Each such pair will be at rest, and merely tend to crush the cylinder On the top surface of the cylinder there will be a downward pressure equal to the weight of the cylindrical column of water above it On the bottom of the cylinder there will be an upward pressure, equal to the weight of a column of water, reaching from the top of the liquid to the bottom of the cylinder These two columns have equal bases, and their pressures are therefore proportional to their heights Their resultant is equal to their difference In other words, the net upward pressure is the difference in weight between two columns of liquid, whose difference in length is the height of the cylinder Clearly, therefore, the cylinder is pressed upwards by a force equal to the weight of a volume of water equal to the volume of the cylinder (Compare *Displacement*)

URANIUM A metallic element not well known in the pure state It is hard, and of an iron colour, somewhat malleable Specific gravity, 18 4 Atomic weight, 120 Symbol, U The only compounds which need be mentioned here are *uranic oxide* (U_2O_3), a yellow powder which unites with bases, forming salts called uranates *Uranate of ammonia* is of a fine deep yellow colour, slightly soluble in water It is used as a pigment under the name of uranium yellow *Uranate of sodium* ($Na_2O\ 2U_2O_3$) is a yellow crystalline salt, almost insoluble in water It is much used for staining glass and porcelain, to which it communicates a beautiful canary colour *Glass coloured with uranium is very fluorescent* (See *Fluorescence*)

URANUS The seventh planet in order of distance from the sun, and the outermost but one of all the members of the planetary system Uranus travels at a mean distance of 1,753,869,000 miles from the sun, his greatest distance being 1,835,561,000, his least, 1,672,177,000 miles Since the earth's mean distance from the sun is 91,430,000 miles, the distance of Uranus from us varies from about 1,927,000,000 to about 1,581,000,000 miles The eccentricity of the orbit of Uranus is considerable, amounting to 0·046,578, in fact, the centre of his orbit lies outside the orbit of Venus, and nearer to the orbit of the earth The inclination of his orbit to the equator is very small, amounting to but 46½ minutes Although far inferior both to Saturn and Jupiter in mass and volume, he far exceeds the earth in both respects His equatorial diameter is estimated at 33,250 miles, though, in the case of a planet situated at so enormous a distance from the sun, considerable doubt must needs exist as to the exact value His polar diameter is doubtless considerably less, but the extent of the compression of Uranus has not been determined His volume exceeds the earth's about 74 times, but his density being but 0 17 (the earth's as 1), his mass barely outweighs the earth's 12½ times It has been asserted that he rotates on his axis once in about 9½ hours, but very little reliance can be placed on this statement, since even in the most powerful telescopes his disc presents an almost uniform appearance

Uranus was discovered by Sir William Herschel on March 13, 1781. At first, owing to its faint light, he regarded it as a comet, but when mathematicians attempted to calculate its orbit on the usual assumption made in that day with respect to comets, viz, that the path was parabolic, unexpected difficulties were found, and Lexell suspected at length that the supposed comet was a planet, moving in an elliptic orbit of small eccentricity around the sun This was found to be the case Further, on carefully calculating the path of the planet retrogressively, it was found that it had been observed before, and recorded as a fixed star by Flamsteed, Bradley, Lemonnière, and Mayer Lemonnière, indeed, had observed it twelve different times, and only failed to recognise its planetary nature through the careless and inexact manner in which he recorded his observations For instance, one observation of this very planet was entered by Lemonniere on a crumpled paper bag which had once contained hair powder

Sir William Herschel proposed that the planet should be called *Georgium Sidus*, in honour of George III Less objectionable by far was the name given by foreign astronomers, who called it *Herschel*. But, for obvious reasons, the name by which it is actually known is preferable to either

Uranus has four recognised satellites, but many suppose there are at least eight, since Sir William Herschel records the discovery of six, and two of those at present recognised are not identifiable with any of those six Mr Lassell is confident, however, that, with the telescopic power employed by Herschel, no satellite could have been discovered, which Mr Lassell's four-feet reflector would not have revealed under the careful scrutiny to which, with its aid, the neighbourhood of Uranus has been subjected

An important part of the history of Uranus is that which is associated with the discovery of Neptune (See *Neptune*)

UREA A normal constituent of urine Formula, COH_4N_2 It is the last term in the series of the products of oxidation of the nitrogenous tissues The quantity depends on the food consumed, and is connected with the amount of labour undergone It may be produced artificially by evaporating down cyanate of ammonia, with which it is identical in composition, or it may be readily prepared from urine by dialysis (See *Dialysis*) It crystallises in long flattened prisms It is very soluble in water and alcohol When heated, it melts, and then decomposes It forms salts with acids, the most characteristic being the nitrate and oxalate, which crystallise readily (See *Animal Nutrition*, *Food, Functions of*)

URIC ACID, or, *Lithic Acid* An important acid normally occurring in urine and other secretions It is a product of the incomplete oxidation of nitrogenous tissue Formula, $C_5N_4H_4O_3$ In combination with ammonia, it is the principal urinary constituent of serpents and other land reptiles, insects, and birds, and is one of the constituents of guano Uric acid is remarkable for the number and importance of its products of decomposition The following is a list taken from *Watt's Dictionary*, vol v p 957, of its principal products of decomposition.—

Pseudo-uric acid.	Hydurilic acid.
Uroxanic acid	Allanton
Alloxan	Glycoluril
Alloxanic acid	Mycomelic acid.
Alloxantin	Oxaluric acid
Barbituric acid	Allanturic acid.
Bromobarbituric acid	Hydantoin
Dibromobarbituric acid.	Hydantoic acid
Voluric acid	Allituric acid
Dilituric acid	Leucoturic acid.
Violantin	Parabanic acid
Dialuric acid.	Dibarbituric acid.
Uramil	Murexide
Thionuric acid	Mesoxalic acid.

(See *Animal Nutrition*, *Food, Functions of*)

URSA MAJOR (The Greater Bear) One of the finest of the northern constellations. Seven stars belonging to this constellation have long been popularly recognised as Charles's Wain (a corruption from Ceorle's Wain, the countryman's waggon). This group has also been known as the Butcher's Cleaver Aratus mentions that the Greek sailors were in the habit of directing their course by this constellation, on account of its proximity to the pole, until the Phenicians taught them to observe in preference the stars forming the constellation Ursa Minor. There are many remarkable double stars and nebulæ within the limits of this constellation. Dubhe, or Alpha Ursæ Majoris, is variable, while the star Delta would seem to have lost a large proportion of its brilliancy during the last few centuries, since of old the equality of "the seven stars" was one of the most remarkable characteristics of the system

URSA MINOR (The Lesser Bear) One of Ptolemy's northern constellations It is distinguished as including the second magnitude star Polaris, the northern pole star This constellation was the Cynosura of the ancients, a name not readily explicable, unless it be supposed that the ancients traced some resemblance between the group formed by the stars 4, 5, β and γ of this constellation, and the tail of a dog (κύων, a dog, οὐρά, a tail) The star Polaris is double, the companion being a well known test of the light gathering power of a telescope. In the great Rosse telescope, however, this star shines like Sirius. For unknown reasons a very small star close by the north pole has been called Blucher.

V

VACUUM TUBES, known also under the names of *Gassiot's Tubes* and *Geissler's Tubes* Mr Gassiot, in examining the discharge of electricity through a vacuum (see *Electric Egg*), proposed to do away with the incumbrance of an air pump by sealing hermetically, tubes exhausted to any required degree, platinum wires being passed through their sides and fused into the glass Geissler of Bonn took up the idea, and under the advice of M Plucker, and with his assistance, produced tubes containing gases of all sorts, at all stages of rarefaction, and of the most varied shape and construction These tubes, apart from their high philosophical interest, form some of the most beautiful luminous objects possible to imagine The general phenomena are described under *Electric Egg* The discharge from an induction coil being passed through a vacuous space, gives rise to magnificent coloured light, filling the whole space, and arranging itself in alternate beds of light and darkness, lenticular shaped, and lying in planes at right angles to the lines in which the discharge is taking place The colour of the light is in general different at the positive and negative electrodes, as are also the shapes of the light and dark beds The colour depends upon the gas with which the tube has been filled before exhaustion, with common air it is purple or red at the positive end, and blue or violet at the negative end In oxygen and nitrogen somewhat similar, but whiter in the case of the former, and in the case of the latter more red at the positive end and more blue at the negative end than in the case of common air In hydrogen the light is greenish blue, in carbonic oxide bright green, yellow at the positive end, and blue at the negative end In ammonia and sulphurous acid gas vivid blue and lilac colours are obtained

In the construction of the tubes the highest ingenuity and skill has been displayed The form of them depends to a certain extent upon whether they are to be used as instruments of investigation, or for purposes of illustration and display In the former case they are generally made symmetrical about the points between which the discharge takes place, in the latter, the shape is varied immensely Tubes of various forms and size, straight and twisted, uniform and irregular, are used Sometimes tubes of smaller size, shaped like vases or bottles, out of which beautiful light pours, are included in exterior large tubes, and in the constructing of these internal tubes use is frequently made of uranium glass and glass of various colours We have seen tubes of various shapes shut up within exterior tubes, and the latter furnished with a hole closed with a glass stopper, so that it can be filled with various solutions for obtaining fluorescent appearances

VALERIANIC ACID A volatile liquid acid of the composition $C_5H_{10}O_2$, met with in nature in Valerian root, and prepared artificially by the oxidation of amyl alcohol, to which it bears the same relation that acetic acid does to vinic alcohol It has a peculiar disagreeable odour, its specific gravity is 0 937, and it boils at 175° C (347° F) It is slightly soluble in water Valerianic acid forms a well crystallised series of salts with bases

VANADIUM A very rare metallic element, almost unknown in the separate state Atomic weight, 51 2, Symbol, V It belongs to the arsenic, antimony, and bismuth group. Vanadium and its compounds have recently been submitted to detailed examination by Professor Roscoe, (*Phil Trans*, 1868, p 1, 1869, p 679), who has obtained results of the highest scientific interest It forms several oxides, a *dioxide* (V_2O_2), a *trioxide* (V_2O_3), a *tetroxide* (V_2O_4), and a *pentoxide* or *vanadic acid* (V_2O_5) The latter acts the part of an acid, and forms a well defined series of salts called vanadates

VAPORISATION (*Vapor*, vapour) In speaking of the expansion of bodies we have mentioned that heat determines the form in which matter exists, and that a liquid may be described as a solid *plus* heat, and a gas is a liquid *plus* heat The addition of the peculiar kind of motion known as heat results in a separation of the molecules of the substance to which it is added to a greater distance than before such addition, and the greater the amount of heat added the further will the molecules be separated In the course of such separation changes of form ensue *Vaporisation* is the change from the liquid to the gaseous condition of matter, and this may take place according to two principal modes, the first of which—*Evaporation*—is the formation of vapour at the surface of a liquid, without the production of bubbles of vapour, and unaccompanied by perturbations of the liquid, the second—*Ebullition*—, the formation of vapour within the mass of a liquid, accompanied by the production of bubbles of vapour, and by a consequent perturbation of the liquid. (See *Boiling-point*, *Evaporation*, *Ebullition*, *Leidenfrost's Experiment*)

VAPORISATION, LATENT HEAT OF See *Latent Heat*.

VAPOUR, AQUEOUS, IN ATMOSPHERE See *Climate, Dew, Humidity, Saturation, Elastic Force*, &c

VAPOUR-DENSITIES, NORMAL According to Dr Odling —

Molecular Formula.	Gas or Vapour	Molecular Weight, 2 vols	Specific Gravity, 1 vol
H_2	Hydrogen.	2	1
Cl_2	Chlorine	71	35·5
Br_2	Bromine	160	80
I_2	Iodine	254	127
O_2	Oxygen.	32	16
S_2	Sulphur	64	32
Se_2	Selenium	159	79·5
N_2	Nitrogen	28	14
HCl	Chlorhydric acid	36·5	18·2
$HgCl$	Calomel	235·5	117·7
HBr	Bromhydric acid	81	40·5
HI	Iodhydric acid	128	64
$(CN)_2$	Cyanogen	52	26
CNH	Prussic acid	27	13·5
$CNCl$	Cyanogen chloride	61·5	30·7
CO	Carbonic oxide	28	14
CCl_2O	Phosgene gas	99	49·5
CH_2O_2	Formic acid	46	23
CO_2	Carbonic anhydride	44	22
CS_2	Carbon disulphide	76	38
CH_4	Marsh gas	16	8
$CHCl_3$	Chloroform	119·5	59·7
CH_4O	Wood spirit	32	16
CH_5N	Methylamine	31	15·5
H_2O	Water	18	9
H_2S	Sulphydric acid	34	17
H_2Se	Selenhydric acid	81·5	40·7
H_2Te	Tellurhydric acid	131	65·5
Cl_2Sn	Stannous chloride	189	94·5
Cl_2Hg	Corrosive sublimate	271	135·5
Et_2Cd?	Cadmium ethyl	170	85
Et_2Zn	Zinc ethyl.	123	61·5
H_3N	Ammonia	17	8·5
H_3P	Phosphine	34	17
H_3As	Arsine	78	39
H_3Sb	Stibine	125	62·5
Cl_3Bi	Bismuth chloride.	316·5	158·2
Cl_3B	Boron chloride	117·5	58·7
Cl_4Si	Silicon chloride	170	85
Cl_4Sn	Stannic chloride	260	130
Cl_4Ti	Titanic chloride	192	96
Cl_4Ta	Tantalic chloride	280	140
Cl_4Cb	Columbic chloride	337	168·5
SO_2	Sulphurous anhydride	64	32
SO_3	Sulphuric anhydride	80	40
Cl_2S_2	Chlorine disulphide	135	67·5
Cl_2SO_2	Sulphur oxychloride	135	67·5
Cl_2CrO_2	Chromium oxychloride	155·5	77·7
N_2O	Nitrous oxide	44	22
N_2O_4	Nitric peroxide	92	46
HNO_3	Nitric acid	63	31·5
$ClNO$	Chloro nitrous gas	65·5	32·7
Cl_3PO	Phosphorus oxychloride	153·5	76·7
C_2H_2	Klumene	26	13
C_2H_4	Ethylene	28	14
C_2H_4O	Aldehyd.	44	22

Molecular Formulæ.	Gas or Vapour	Molecular Weight, 2 vols	Specific Gravity, 1 vol
C_2HCl_3O	Chloral.	147 5	73 7
C_2Cl_4O	Perchloral	182	91
$C_2H_4O_2$	Acetic acid	60	30
$C_2H_6Cl_3O_2$	Trichloracetic.	163 5	81 7
C_2H_6	Ethene	30	15
C_2H_5Cl	Ethyl chloride	64 5	32 2
$C_2H_4Cl_2$	Ethylene dichloride.	99	49 5
C_2H_6O	Alcohol	46	23
C_2H_6S	Mercaptan	62	31
$C_2H_6O_2$	Glycol	62	31
C_2H_7N	Ethylamine	45	22 5
C_2H_8N	Ethylen diamine	60	30
C_3H_6O	Acetone	58	29
$C_4H_8O_2$	Acetic ether	88	44
$C_4H_{10}O$	Ether	74	37
$C_4H_{10}S$	Ethyl sulphidide	90	45
$C_4H_{10}S_2$	Ethyl disulphide	122	61
C_5H_{10}	Amylene	70	35
C_6H_6	Phenene	78	39
C_6H_6O	Phenol	94	47
C_6H_7N	Aniline	93	46 5
C_7H_6O	Benzoic aldehyd	106	53
$C_7H_6O_2$	Benzoic acid	122	61
$C_{10}H_8$	Naphthalene	128	64
$C_{10}H_{16}$	Turpentine	136	68
$C_{10}H_{16}O$	Camphor	152	76

VAPOUR DENSITIES, ANOMALOUS According to Dr Odling —

Molecular Formulæ	Gas or Vapour	Molecular Weight, 1 vol	Specific Gravity 1 vol.
P_2	Phosphorus	62	62
As_2	Arsenicum	150	150
As_2O_3	White arsenic	198	198
$AlCl_3$	Aluminic chloride	134	134
$CrCl_3$	Chromic chloride	159	159
$FeCl_3$	Ferric chloride	162 5	162 5
		3 vols	1 vol
HgS	Cinnabar	232	77 3
Cl_2O_3	Chlorous anhydride.	119	39 7

Molecular Formulæ	Gas or Vapour	Molecular Weight, 4 vols	Specific Gravity, 1 vol
Hg_2	Mercury	400	100
Cd_2	Cadmium	224	56
N_2O_2	Nitric oxide	60	15
Cl_2O_4	Perchloric oxide	135	34
H_2SO_4	Sulphuric acid	98	24 5
NH_4Cl	Ammonium chloride	53 5	13 4
NH_4CN	Ammonium cyanide	44	11
NH_5S	Ammonium sulphydrate	51	13
PCl_5	Phosphorus pentachloride	208 5	52 1
VCl_6	Vanadic hexachloride	350	87 5

The greater number of these anomalies are explicable or removeable

VAPOURS, DETERMINATION OF DENSITY OF The determination of the density of vapours is an important physical problem The definition of the density of a vapour, at a given temperature and pressure, is the ratio which the weight any volume of the vapour bears to the weight of the same volume of air at the same temperature and pressure. It is necessary, therefore, to determine the weight of a known volume of the vapour, or the volume

of a known weight, at the given temperature and pressure. The weight of a volume v of air at the given temperature and pressure is calculated by the well-known formula—

$$* w = v \times 0{\cdot}001293 \times \frac{1}{(1 + a\,t)} \cdot \frac{H}{76},$$

where w is the weight in grammes, v the volume in cubic centimetres, a the coefficient of expansion for air per degree centigrade ($a = 0{\cdot}003665$), t the temperature in centigrade degrees, and H the barometric height in centimetres. To determine, therefore, the density of the vapour, we must find by experiment the weight of the volume v of the vapour at the temperature t and pressure H, and divide by w.

There are two methods of determining the relation existing between the volume and weight of a vapour at a certain temperature and pressure. The first, that of Gay-Lussac, is the following:—A graduated tube, closed at one end, is filled and inverted over mercury, and round the tube there is a cylinder of glass which is filled with water, and covers the tube completely. The glass cylinder is open at both ends, and at one of the ends dips below the mercury in the trough in which the graduated tube is inverted, so that the water rests on the surface of the mercury; and the vessel in which the mercury is contained is of iron, and can be placed over a heating apparatus, and thus the whole apparatus, including the mercury and the water, can be raised in temperature. The temperature of the water is determined by thermometers suspended in it, and by a stirring apparatus, the temperature is kept the same throughout it. A very small globe of extremely thin glass is prepared, and the weight of the glass having been ascertained, the little globe is filled completely with the liquid whose density is to be determined, sealed up, carefully dried and weighed again, so that the weight of the liquid is known. This is passed under the mercury into the interior of the graduated tube, and heat is applied to the apparatus. Soon the bulb of glass bursts, and when the temperature is raised sufficiently, the whole is converted into vapour, and fills the upper part of the graduated tube, the mercury being driven down it until it stands at a certain height, h let us suppose. The temperature and the barometric height are then noted. If the latter (as we have supposed it in the equation above, which represents the weight of a volume of air) be denoted by H, the $H - h$ will be the pressure at which the volume is measured. The volume being noted, the density of the vapour is calculated, as we have indicated above. It is evident that this method is only applicable to cases in which the liquid is easily vaporised. There are, however, many liquids which do not vaporise even at a temperature of boiling water, and the density of these cannot be ascertained in this way.

The second method of determining the weight of a certain volume of vapour is due to Dumas. A light glass globe capable of containing half a litre or so, (about one tenth of a gallon,) is employed, and the neck of it is drawn out to a long stem, terminating in a capillary point. The weight of the globe is determined accurately, and a considerable quantity of the substance whose density is to be examined is put into it. If the substance be a solid, such as iodine, it must be put in before the capillary neck is made. The vessel is then placed in an iron pot in which there is water, (or if a higher temperature than that of boiling water is required, a saturated solution of some salt, and sometimes oil or fusible metal,) and in such a position that only the capillary extremity of the tube may be above the surface of the liquid, and heat is applied to the iron vessel. When the temperature rises sufficiently, the liquid within the glass globe boils, and the vapour issuing from the capillary tube escapes and carries away the air within the globe. After some time the whole excess of the substance has been driven off, and if the experiment be properly performed, almost all the air is carried away with it. The globe is then sealed with the aid of a blowpipe, the temperature of the liquid surrounding it, and the barometric height being noted at the time of sealing; and after being allowed to cool, it is carefully wiped and weighed. The vessel is now put under mercury or water, and the end of the capillary tube is broken off. The mercury or water rushes up and fills the globe, a vacuum having been created by the condensation of the vapour and any small quantity of air that may have been left behind in the globe is then noticed and allowed for in the subsequent calculations. On weighing the vessel full of the liquid at a known temperature, and deducting the weight of the glass, it is easy to calculate the volume of the globe. From the two previous weighings, we can also calculate the weight of the globe full of the vapour in question; and dividing this weight by the weight of an equal volume of air at the proper temperature and pressure, the density of the vapour is ascertained.

* If w' be the weight in grains, v' the volume in cubic inches, a' the coefficient of expansion for air per degree Fahrenheit $\left(a' = \frac{1}{490{\cdot}9}\right)$, t' the temperature in degrees Fahrenheit, and H' the barometric height in British inches, $w' = v' \times 0{\cdot}3095 \times \frac{490{\cdot}9}{490{\cdot}9 + t'} \times \frac{H'}{29{\cdot}92}$.

VARIABLE AND TEMPORARY STARS, SPECTRA OF. Mr Huggins and Dr Miller have examined the spectrum of a star in the constellation Northern Crown, which from being almost invisible suddenly blazed out until it rivalled the brightest star in the sky. Its spectrum was seen to be of the ordinary stellar type, viz.—a bright spectrum crossed by fine black lines, but upon this was superposed another spectrum consisting of three very bright bands coincident with the bright bands of hydrogen; as the brightness of the star waned, these bright lines faded and finally disappeared. The inference from this is almost irresistible that the brightness was due to a sudden conflagration of the star, increasing its brilliancy almost eighthundred-fold. Similar phenomena have been observed, though not on so large a scale, in other stars. (See *Stars, Spectra of*.)

VARIABLE PRISM. Boscovich proposed to form a prism with a variable angle, consisting of a hemispherical plano-convex lens, moving in a concave lens of the same curvature; by altering the position of the convex lens the two plane faces could be inclined to one another at any desired angle. (See *Prism*.)

VARIABLE STARS. See *Stars, Variable*.

VARIATION OF THE COMPASS. The angle of declination is frequently spoken of as the *variation of the compass*. (See *Declination*.)

VARIATION OF THE MOON. See *Lunar Theory*.

VARIATION OF TERRESTRIAL MAGNETISM. See *Magnetic Variation*.

VEGA (Arabic.) The star *α* of the constellation Lyra. One of the brightest stars in the northern heavens. It has many small companions.

VEGETABLE ALBUMEN. See *Albumen*.

VEGETABLE NUTRITION. The chemical functions of the vegetable and the animal, as far as nutrition is concerned, are opposed and complementary to one another. The animal starts with highly complex substances and by a process of oxidation converts them into much simpler compounds, in many cases into the simplest products of all—water and carbonic acid. The vegetable, on the contrary, starts with the simplest substances—water, carbonic acid, ammonia, and the mineral constituents of the soil, and by a process of synthesis, gradually builds up compounds of the highest degrees of chemical complexity. Perhaps the most important function of the vegetable world is to restore the balance of the constituents of the atmosphere which animal life alone would soon render so vitiated as to prevent the continuance of life. During respiration the animal world is constantly pouring into the atmosphere torrents of carbonic acid, and abstracting oxygen; the vegetable world, on the other hand, is just as unceasingly absorbing carbonic acid, fixing the carbon and restoring the oxygen to the atmosphere. A plant is nourished through its roots, the leaves acting as lungs. The rain descending through the air carries with it carbonic acid, ammonia, and nitric acid. These percolating through the soil dissolve small quantities of the mineral ingredients present, and the whole is brought in contact with the roots in a fit state for absorption. The plant can obtain carbonic acid and water from the atmosphere, but in many cases ammonia and some of the requisite mineral ingredients have to be supplied artificially. It is on this account that farm-yard manure and the excreta of towns are of such great value in agriculture, containing as they do large quantities of ammonia-forming material, together with nearly all the mineral ingredients of the vegetable food previously consumed by the animal. (See *Animal Nutrition*, and *Soils, Chemistry of*.)

VEGETATION, INFLUENCE OF, ON CLIMATE. See *Rain, Forests*, &c.

VELOCITY (*Velocitas*, from *Velox*, swift; allied to *Volo*, to fly.) Swiftness or rapidity of motion. In order to measure velocity we require both a unit of space and a unit of time. One body is said to have a greater velocity than another when it moves over a greater space in the same time, or an equal space in less time. The velocity of a body is *uniform* when it passes through equal spaces in equal times; and *variable* when the spaces passed through in equal times are unequal. Uniform velocity is measured by the length of path passed over in a unit of time. This length is usually expressed in feet, and the time in seconds. Frequently, however, other units are chosen; thus, a train may proceed with a speed of 40 miles an hour, a ship may sail with a speed of 10 knots an hour. Velocity expressed in other units may, however, be readily reduced to feet per second. For example, one mile an hour is $1\frac{7}{15}$ feet per second. Variable velocity at any instant is measured by the mean velocity for an infinitely small space commenced at that instant. It is the space the body would describe in a unit of time if from that particular instant the velocity remained constant. For instance, a horse may travel from one place to another with a variable velocity, but we may say that at a particular instant he is running at a speed of 20 miles an hour. We mean that for a small distance he moves with a speed which, if maintained for an hour, would carry him over 20 miles. The velocity of a body is *accelerated* when it passes through a greater space in one unit of time than in the preceding

unit, and it is *retarded* when a less space is passed through in each successive portion of time. *Absolute* velocity is the velocity of a body, considered without reference to the motion of any other body. *Relative velocity* is that which has respect to the velocity of another moving body. *Angular* velocity is the velocity of a body revolving about a fixed point or axis, measured by the angle through which it turns in a unit of time. The angular velocity of a planet is estimated by the angle described by the radius vector, that is, by the line joining it with the sun. The velocity with which a body begins to move is termed *initial* velocity. When the velocity increases uniformly, the increase per second is termed the acceleration. The velocity of a body at any instant in the case of uniform acceleration, is found by adding to or subtracting from the initial velocity the product of the acceleration by the time. (See *Acceleration*.)

VELOCITY OF LIGHT. The velocity of light cannot be found by calculation, but it has been determined by direct observation by several observers.

I. Römer found that the calculated time of the eclipses of Jupiter's satellites did not agree with observation, there being fifteen minutes difference according to whether the earth was in that part of her orbit nearest to or farthest from Jupiter; he concluded, therefore, that this difference was due to the time occupied by light in travelling a distance equal to the diameter of the earth's orbit. From these data he deduced a velocity of 167,000 geographical miles per second.

II. From the aberration of the fixed stars a velocity has been deduced of 166,072 geographical miles per second.

III. Fizeau measured the velocity of light in a space of a few miles by making it pass between the teeth of a wheel revolving with enormous velocity, after travelling the full distance and back again. By observing the distance one of the teeth had moved during the time the ray of light had taken for the double journey, he calculated the velocity to be 185,000 miles in a second.

IV. Foucault, assisted by Fizeau and Breguet, measured the velocity of light in the space of four metres. A plane mirror is made to rotate several hundred times per second; a beam of light is then (after passing through a system of cross wires) allowed to fall on the mirror. It is reflected by this to a stationary reflector two metres distant, which sends the ray back again, whence it is reflected by the revolving mirror back through the original system of cross wires to an eye piece. If the light reflected from the revolving mirror comes back to it so rapidly that the revolving mirror has had no time to move appreciably, the first and second images of the cross wires will appear superposed in the eye piece; but if the revolving mirror has been able to move through a sensible angle whilst the light has travelled the four metres, the two images of the system of wires seen in the eye piece will not coincide, but will be separated to a greater or less extent according to the velocity of the mirror. From data obtained in this manner Foucault deduced a velocity of 191,000 miles per second.

VELOCITY OF SOUND. That sound takes an appreciable time to travel, and that it travels with far less velocity than light, is frequently observed when a man is seen at two or three hundred yards distance knocking down with a hammer or beating a carpet. The blow is seen to be given some time before the sound is heard. If we stand in the centre of an arc of soldiers who fire their rifles simultaneously, we hear a single report; but if we stand at one end of the arc we hear a "rattle." The sound of the several reports takes longer to reach us according as the soldiers are farther off. When an electrical discharge in the form of a flash of lightning takes place, all parts of the course of the flash are traversed sensibly at the same instant. The thunder endures often for several seconds. The thunder produced by the flash when nearest to the earth is heard first, and if any parts of the lightning's path are nearly at the same distance from the auditor, the sounds produced at those parts will reach his ear at the same time and produce a loud crash of sound.

With regard to the actual velocity of sound in air, it has been observed that an exceedingly loud sound travels faster than a less loud one. Under ordinary circumstances the limit of distance at which feeble sounds are audible prevents our recognition of this. In the arctic regions, where the air is often extremely still and homogeneous, sounds can be heard at a great distance, and it has been observed that at a great distance the report of a cannon is heard before the word of command to fire it. No accurate experiments have been performed to connect the loudness of a sound—that is, the amplitude of the vibration with the rate of propagation so as to confirm the mathematical conclusion that loud sounds should travel faster than feeble ones. Within the range of sounds employed in music this difference of rate, due to difference of loudness is not apparent, the feeblest audible notes occupying their proper place amongst those of greater intensity.

Further, the pitch of the note (see *Pitch*), appears to be without influence upon its rate of propagation. The familiar proof of this is afforded by the fact that the several notes com-

posing an air of music are heard at their proper intervals at whatever distance the auditor is placed from the musician, showing that the notes of various pitch travel sensibly at the same rate

Again, the same preservation of time and harmony is a proof that the "tone-colour" (see *Colour of Notes*), is without influence, for we find that when a band of music consisting of wind, string, or membrane instruments, is heard at a distance, the harmony and tune are preserved

The most exact determinations of the velocity of sound in unconfined air are based upon the explosion of powder, and, therefore, from what has been said above the results are only strictly true for the sounds examined We may take the velocity of sound at 32° F, and 30 inches pressure as being 1093 feet a second Experimental determinations agree very closely with this number, which accords also with the velocity deduced by La Place from theory La Place concluded that when a wave of compression, followed by a wave of rarefaction passes through the air, although the total heat liberated in the region of compression is absorbed in the region of rarefaction, yet the momentary heating effect assists the passage of the sound The formula given by La Place is $v = \sqrt{\frac{g h}{d} k}$ In this v is the velocity measured in feet per second, g is the accelerating force of gravity or 32 feet per second, h is the elasticity of the gas measured by the height of the mercurial column which the gas supports reduced to 32° F, d is the specific gravity of the gas referred to mercury at 32° F, as unity, and k is the ratio between the capacity for heat of the gas by constant pressure to its capacity by constant volume (see *Specific Heat*) For air the above formula becomes $v = 1074\ 56 \sqrt{1 + a t}$ feet, where a is the coefficient of expansion for 1° F, and t is the temperature above 32° F Thus, at 32° F, the expression becomes $v = 1074\ 56$ feet At 60° F it becomes $1074\ 56 \sqrt{1 + \frac{60}{491\ 4}}$ or 1139 It appears also from the above formula that the rate increases with the temperature, and that it is independent of the pressure In the same manner the velocity of sound in other gases may be calculated if we know their densities, and the above ratio k of their specific heats at constant temperature and at constant volume Further, this ratio can be determined if we know the velocity The velocity of propagation in any medium can also be determined by finding the note produced by a tube of known length filled with the gas and comparing it with that produced under like circumstances by air

The velocity of sound in liquids is expressed by the following formula $v = \sqrt{\frac{g}{\gamma}}$, where γ represents the shortening which a horizontal column of liquid one foot in length would suffer, if it were compressed by a force equal to its weight Unfortunately, the compressibility of liquids (see *Compressibility*) cannot be said to have been determined with great accuracy in any case From direct experiments in the Lake of Geneva, the velocity of the sound originating in a bell struck under water, and heard by means of a species of long ear-trumpet, one end of which was also under water, was found to be 4708 1 feet per second

The velocity of sounds in solids can be derived theoretically from the above formula $v = \sqrt{\frac{g}{\gamma}}$. But the compression of solids is even less accurately determined than that of liquids It is usual to assume that the compressibility by pressure is equal and opposite to the expansion, or rather elongation, when a pulling force is applied, and this has been determined with some accuracy in a few cases The rate of propagation of sound in solids may, however, be easily and accurately found by experiment, and compared with that through air If n be the number of vibrations in a second, in a column of air, in a tube of length l, which is sounding its fundamental note, we know that the length of the sonorous wave is $2l$, therefore in one second we have a length of $2nl$ in vibration—that is, the sound will have travelled $2nl$ or $v = 2nl$ If now we take a rod of a solid substance, say wood, and set it in longitudinal vibration, we find a higher note produced as a fundamental note—that is, when the rod is held in the middle Let n' be the number of vibrations per second Then as before if v' be the velocity in the solid $v' = 2n'l$, and therefore comparing the two $v' = v \frac{n'}{n}$ Thus, if we take an open organ-pipe, and determine its fundamental note with air, then find the fundamental note of a willow rod of the same length, we shall find that there are sixteen times as many vibrations of wood as of the air—that is, we should get a note four octaves higher This shows that the sound travels sixteen times as fast in willow wood as in air

The following table shows the relative velocity of sound, through several solid substances, as determined in the above manner by Chladni. The velocity in air is taken as unity —

Whalebone,	$6\frac{2}{3}$	Pearwood,	$12\frac{1}{2}$
Tin,	$7\frac{1}{2}$	Ebony,	$14\frac{2}{3}$
Silver,	9	Birch,	$14\frac{2}{3}$
Walnut,	$10\frac{2}{3}$.	Cherry,	15
Brass,	$10\frac{2}{3}$	Willow,	16
Oak,	$10\frac{2}{3}$	Glass,	$16\frac{2}{3}$
Earthen Pipes,	10 to 12.	Iron or Steel,	$16\frac{2}{3}$
Copper,	12	Deal,	18

These numbers are, however, of only approximate exactness, since different samples of the same body vary to some extent in the rate with which they conduct sound. No exact measurements have been made to connect the loudness of the sound with the note, in the case of solid or liquid bodies.

VELOCITY, VIRTUAL (*Virtuel*, from L. *virtus*, strength, power: virtual signifies in effect, not in fact.) A term given by Duhamel, to a minute hypothetical displacement or motion, assumed in mechanical analysis to facilitate the investigation of statical problems. When a system of particles is in equilibrium, and we suppose each of them placed in a position indefinitely near that which it really occupies, without disturbing the connection of the parts of the system with each other, the line which joins the first position of a particle with the second is called the *virtual velocity of that particle*, and the product of the intensity of the force, acting on the particle by its virtual velocity estimated in the direction of the force, is termed the virtual moment of the force. The principle of virtual velocities may be thus enunciated:— If the system be in equilibrium, the sum of the virtual moments of all the forces is zero, whatever be the displacement; and, conversely, if the sum of the virtual moments be zero, the system is in equilibrium. This principle may be considered as the golden rule of mechanics. It is easily verified with respect to the simple mechanical powers, but it applies immediately to all questions respecting equilibrium, or to all statical problems, and it frequently furnishes a very easy method of determining the relation between forces in equilibrium. From this principle it follows that, in the case of all the mechanical powers, the product of the power by the space, through which it moves in its own direction, is equal to the product of the weight by the space through which it moves in the vertical direction. Thus if the power of 10 lbs raise a weight of 50 lbs through a height of 1 foot, the power must descend through 5 feet. The fact here illustrated is sometimes stated thus, "What is gained in power is lost in speed."

VENA CONTRACTA. See *Flow of Liquids*.

VENTRAL SEGMENTS. See *Nodes and Segments*.

VENUS. In astronomy the brightest and most beautiful of all the planets, and the second in order of distance from the sun. The mean distance of Venus from the sun is 66,134,000 miles; her greatest, 66,586,000; her least, 65,682,000. As the earth's mean distance from the sun is 91,430,000 miles, it follows that the distance of Venus from the earth varies between about 25,000,000 and about 158,000,000 miles. The eccentricity of her orbit is small, not exceeding .00685. Its inclination to the ecliptic is 3° 23′ 31″. Her mean sidereal revolution occupies 224.700787 days, and the returns to successive conjunctions are separated by a mean interval of 583.920 days. Her diameter is estimated at about 7510 miles; her volume, 0.855, the earth's being 1; her density almost exactly equal to the earth's; and therefore her mass bears to the earth's the same proportion that her volume bears to the earth's volume.

As Venus travels within the orbit of the earth she is never seen in opposition to the sun. She passes through a series of phases resembling those of the moon, only that she varies greatly in apparent size while passing through them. When she presents a full disc, she is in superior conjunction with the sun, and lost to view in his beams, except in powerful telescopes. At this time also her apparent diameter is least. When between us and the sun she turns no part of her illuminated surface towards us, and as she is necessarily very close to the solar disc, she is only visible in good telescopes. Her apparent diameter then has its greatest value. In other positions she shines with greater or less brilliancy, according to her distance from us, and the portion of her illuminated surface she turns towards us. Her greatest elongation from the sun varies in different synodical revolutions between 45° and 47° 12′.

The telescopic observation of this planet is difficult on account of the exceeding brilliancy of her surface. "Its intense lustre," says Sir John Herschel, "dazzles the sight, and exaggerates every imperfection of the telescope; yet we see clearly that its surface is not mottled over with permanent spots like the moon; we perceive in it neither mountains nor shadows, but a uniform brightness, in which we may indeed fancy obscurer portions, but can seldom or never rest fully satisfied of the fact. It is from some observations of this kind that both Venus and Mercury have been supposed to revolve on their axes in about the same time as the earth." The inclina-

tion of the planet's equator has been judged to be large, the estimated values varying between 50° and 70°, but very little reliance can be placed on the observations by means of which these estimates have been formed. As for De Vico's estimate of the planet's rotation-period, with its claim to accuracy as far as the second decimal place of seconds of time, no more reliance can be placed upon it than on the inclination estimates. Indeed, it would be barely possible to secure the asserted degree of accuracy, even though Venus presented obvious and easily recognisable marks upon her surface, and though these had been watched since the telescope was first invented. Considering that, on the contrary, it is barely possible to see marks at all upon her surface; that these marks cannot be rediscovered; and that not much more than a century has elapsed since any of them have been recognised, it will be seen how little reliance can be placed on a rotation period which claims to be within one hundredth part of a second of the truth. It is far from improbable, indeed, that Sir John Herschel's opinion must be accepted, according to which, "the most natural conclusion from the very rare appearance and want of permanence of the spots is, that we do not see, as in the moon, the real surface of the planet, but only its atmosphere, much loaded with clouds, serving to mitigate the otherwise intense glare of their sunshine."

Venus, on account of her proximity to the earth, produces recognisable perturbations of the earth's motions. One effect resulting from a relation of commensurability between the orbital periods of Venus and the earth, merits special mention. Thirteen sidereal revolutions of Venus are accomplished in a period very nearly equal to eight years, that is, to eight sidereal revolutions of the earth. It follows that every fifth conjunction takes place nearly along the same line through the sun. Hence arises an accumulation of effects resembling in their general character, though far less considerable, the *great inequality* of Saturn and Jupiter. (See *Inequality*.) The period of this long inequality is about 240 years, the maximum effect on acceleration or retardation of either planet being only a few seconds of arc. Mr. Airy, the Astronomer Royal for England, detected this inequality, and the similar action of Venus upon the moon.

Venus, like Mercury, but less often, crosses the face of the sun at certain times. This phenomenon, called a *transit of Venus*, is of the utmost importance to the astronomer, as affording a means of estimating the distance of the sun from the earth. We owe to Halley the suggestion that the transits of Venus might thus be utilised.

It will be obvious that the nearer a planet approaches to the earth the more effective will be any terrestrial distance in causing an apparent change of the planet's place on the celestial sphere. Thus Venus, which approaches us within 25,000,000 miles when in inferior conjunction, would exhibit for any change of place on the part of an observer, or for any distance separating two observers, a change of place 3½ times as great as that which would affect the sun, which lies about 91,500,000 miles from the earth. But we cannot effectually observe the parallactic displacement of Venus upon the celestial sphere, since it is exceedingly small, and we cannot compare her place with the place of any fixed star. But if, when in inferior conjunction she lies so near one of her nodes as to be upon the sun's face, we might very readily determine her parallactic displacement on the solar disc; only, instead of being 3½ times the solar parallax, it would be but 2½ times that amount, being in fact represented by the difference between the parallactic displacements of Venus and the sun upon the celestial sphere. But in effect there is a difficulty even as regards this method; for the planet is in motion, and in order to compare two observations, we must be sure they are made at exactly the same instant, a matter of some difficulty when the two observers are on opposite sides of the earth. Now, Halley suggested that, instead of observing the position of Venus on the sun's face at any assigned instant, the observers should record the interval of time occupied by Venus in crossing the solar disc. As the effect of parallax would be to make her traverse different chords, as seen by the two observers, there would obviously be a difference in the duration of transit as recorded by them; and this difference would suffice to enable the astronomer, by appropriate calculations, to deduce the sun's distance.

The objection to the method thus described (necessarily only in a general manner) lies in the fact that it is absolutely necessary that each observer should see the whole transit; and as a transit may last several hours (as many as eight) and the earth accomplishes a considerable part of a rotation in such an interval, it is difficult to find a northern and a southern station, at each of which the observer will be well situated both at the beginning and at the end of the transit. For, given a certain epoch during the occurrence of a transit, two observers can be placed so that the parallactic displacement of Venus may be the greatest possible; but it by no means follows that given two epochs, (as in this case the beginning and the end of the transit), two observers can be so placed that the parallactic displacement of Venus may be even considerable at both epochs.

Hence it was proposed by Delisle that another method should be adopted. According to his plan two observers should both observe one and the same phase, internal contact at ingress, (that is, the moment at which Venus is first just within the sun's limb,) or internal contact at egress, (that is, the moment when she is just about to cross the sun's limb and so pass off his surface), that these observers should note the *absolute time* at which the phase is visible to them, so that afterwards the observed difference of time should supply the means of estimating the sun's distance. For this plan it is obviously necessary that the latitude and longitude of the observers' stations should be very accurately determined.

Each plan has its advantages and disadvantages, and in different transits Halley's method may be preferable to Delisle's, or Delisle's to Halley's, according to the circumstances of the transit, and according to the nature of those parts of the earth at which the stations have to be placed.

Observations of the transit which occurred in June 1761 were not successful. Those made during the transit of June 1769 were more satisfactory, and the estimate of the sun's distance deduced from them by Encke remained for a long time in vogue in our treatises on astronomy. Recently, however, other modes of measuring that element led to results so discordant with Encke's estimate that doubts were thrown on the accuracy of the observations made in 1769, and on the competence of the observers. The careful examination of the matter by Professor Simon Newcombe of America, and (on a more satisfactory plan) by Mr Stone of the Greenwich Observatory, has shown that the cause of the discrepancy is to be looked for in a phenomenon due to irradiation which causes a black ligament to appear between the disc of Venus and the sun's limb near the time of the internal contacts.

The accuracy of the general method having been thus re-established, astronomers look hopefully to the transits which are to take place in 1874 and 1882, to afford them a new and more accurate estimate of the sun's distance. The Astronomer-Royal long since called the attention of astronomers to the subject, and has published a series of papers indicating the manner according to which, in his opinion, the transit can be most satisfactorily utilised. Owing, however, to his having unfortunately adopted an approximate instead of an exact process, in dealing with the calculations which the problem involves, the results are not so satisfactory as could be desired. In particular, his selection of Delisle's method for the transit of 1874, while Halley's method is left for the transit, 1882, alone is unfortunate, because it chances that when the problem is treated in an exact manner Halley's method is found to be wholly inapplicable in 1882, while, on the other hand, it can be applied very advantageously to the transit of 1874. It is also a misfortune, and may perhaps injuriously affect the interests of science for years to come, that a number of excellent stations in India should have been wholly overlooked in Mr Airy's treatment of the subject. An exact investigation of the problem by the present writer will be found in the *Monthly Notices of the Royal Astronomical Society*, vol xxix. It is right, however, to mention that the Astronomer-Royal has expressly described his examination of the subject as not intended to exhibit exact relations, and were it not probable that the selection of places for observing the transit will be wholly founded upon his papers no correction would have been necessary.

VERDIGRIS. See *Acetates*.

VERMILLION. See *Mercury*, *Sulphide*.

VERNAL EQUINOX. See *Equinox*, *Equinoctial*.

VERNIER. (Named after the inventor.) A short graduated scale made to slide along a larger scale or *position circle* so as to read to fractions of divisions. It is graduated so that ten divisions on the vernier equal nine divisions on the larger scale. By seeing which of the divisions coincide in the two scales it is easy to read to a tenth of a division.

VERTICAL CIRCLE. In astronomy a great circle of the celestial sphere passing through the *zenith* and *nadir*, and therefore at right angles to the horizon plane.

VESTA. An asteroid, discovered by Olbers. (See *Asteroids*.)

VIA LACTEA. (The Milky Way.) See *Galaxy*.

VIBRATION, AMPLITUDE OF. See *Amplitude of Vibration*.

VIBRATION, APPROACH CAUSED BY. Professor Guthrie has found that, when a vibrating tuning-fork, or other sonorous body, is held near a delicately suspended substance, the latter approaches the fork. The experiment is conveniently made by hanging a piece of cardboard in a vertical plane from a light splinter of wood, counterpoised at the other end, and suspending the whole by a piece of unspun silk. When the face, the side, or the ends of the sounding fork are approximated to the card, the latter swings towards the fork. This phenomenon is probably due to the substance which receives the vibrations not being a perfect transmitter or reflector of sound, and it converts a portion of the sonorous elastic wave into true currents, which, on account of dispersion, suffer rarefaction, so that the bodies are urged together by the pressure of the air, as in the experiments of Clement and Desormes.

In a paper which appeared in the *Philosophical Magazine* for November 1870, Professor Guthrie gives a description of his experiments, and arrives at the following conclusions —

"Whenever an elastic medium is between two vibrating bodies, or between a vibrating body and one at rest, and when the vibrations are dispersed in consequence of their impact on one or both of the bodies, the bodies will be urged together

"The dispersion of a vibration produces a similar effect to that produced by the dispersion of the air current in Clément's experiment, and, like the latter, the effect is due to the pressure exerted by the medium, which is in a state of higher mean tension on the side of the body farthest from the origin of vibration than on the side towards it

"In mechanics, in nature, there is no such thing as a pulling force Though the term attraction may have been occasionally used in the above to denote the tendency of bodies to approach, the line of conclusions here indicated tends to argue that there is no such thing as attraction in the sense of a pulling force, and that two utterly isolated bodies cannot influence one another

"If the ethereal vibrations, which are supposed to constitute radiant heat, resemble the aerial vibrations which constitute radiant sound, the heat which all bodies possess, and which they are all supposed to radiate in exchange, will cause all bodies to be urged towards one another"

VIBRATION OF A STRETCHED STRING If an elastic round string, of uniform thickness and certain length, thickness, and weight, be stretched by a given force, it will vibrate when plucked at a definite rate, and therefore give rise to a musical note of given pitch, if it vibrates beyond a certain rate (16 times in a second) If l be the length of a string, w its weight, s the force with which it is stretched, g the accelerating force of gravity ($=32$ feet per second), then t the time for a complete oscillation is

$$t = 2\sqrt{\frac{w\,l}{g\,s}}$$

And, therefore, if n be the number of oscillations in a given time

$$n = \frac{1}{2}\sqrt{\frac{g\,s}{w\,l}}$$

If ρ represents the specific gravity of the substance out of which the string is made, and if r is the diameter of the string, then $w = \pi r^2 l \rho$, and therefore $n = \frac{1}{2\,r\,l}\sqrt{\frac{g\,s}{\pi\,\rho}}$ This formula, which has been gradually established from theoretical grounds, is fully confirmed by experiment It may be stated in words as follows —The number of vibrations which a stretched string performs in a given time—in other words, the pitch of its fundamental note—varies inversely as its diameter, inversely as its length, directly as the square root of the force with which it is stretched, and inversely with the square root of the specific gravity of the substance of which it is made Thus, if we have a string vibrating 100 times in a second, and we wish to get the octave higher (*i e*, two hundred vibrations per second), by merely altering the length we must make the string half as long If, preserving the same length, we wish to get the higher octave by altering the stretching force, we must make the latter four times as great, and so on

VIBRATIONS, GRAPHIC REPRESENTATION OF. See *Graphic Representation of Vibrations*

VIBRATIONS, LONGITUDINAL See *Longitudinal Vibrations*

VIBRATIONS, PERMANENT See *Permanent Vibrations*

VIBRATIONS, PROGRESSIVE See *Progressive Vibrations*

VIBRATION (TRANSVERSAL) OF AN ELASTIC ROD If an elastic rod be fastened rigidly at one end and set vibrating, the number of vibrations in a given time—that is, the pitch of the note is expressed by the equation

$$n = \frac{t}{l^2}\sqrt{\frac{g\mathrm{E}}{\rho}}$$

in which n is the number of vibrations, t the thickness in the direction of vibration, l the length, g the accelerating force of gravity, E the modulus of elasticity and ρ the specific gravity of the material It is seen from this that the pitch of the note produced by such a rod varies directly as its thickness in the direction of vibration, and inversely as the square of the lengths Thus, if two pieces of the same steel spring, when clamped at one end, give notes an octave apart, we know that the one vibrates twice as fast as the other, and, from the above formula, that the second is four times as long as the first It appears also that, if two rods are made of the same material, and are of the same length, but one is twice as thick in the direction of vibration as the other, the first will sound the octave above the second The width of the rod is of no influence upon its rate of vibration, and this indeed we might anticipate from the fact, that if two exactly similar rods were vibrating side by side, and therefore isochronously, the vibration

of neither would be interfered with by joining them together, so as to form a rod of the same thickness and length, but double the width.

VIBRATORY THEORY OF LIGHT See *Undulatory Theory of Light*

VINDEMIATRIX. (She that gathers grapes, or the vintage star) The star ε of the constellation Virgo

VIRGO (The virgin) A sign of the zodiac The sun enters this sign on about the 23d of August, and leaves it on about the 23d of September The constellation Virgo occupies the zodiacal region corresponding to the sign Libra This constellation is remarkable for the great number of nebulæ which have been found within its limits

VIRTUAL FOCUS The point behind a convex mirror, from which divergent rays, reflected from it, appear to radiate (See *Convex Mirror, Focus*)

VIRTUAL IMAGE An image without material existence, in effect, though not in fact (See *Images, Virtual, Real*)

VIS ACCELERATRIX Accelerating force (See *Acceleration*)

VIS INERTIÆ (Lat) Literally, the force of inactivity The term was employed by Newton to signify a power implanted in all matter, by which it resists any change endeavoured to be made in its state, that is, the power by virtue of which it becomes difficult to change the state of rest or motion A distinction is made between *vis inertiæ* and *inertia*, the former implying the resistance itself which is given by a body to any force, and the latter merely the property by which the resistance is given The property of matter which is set forth in the law of *inertia* (First Law of Motion), is, however, simply absolute passiveness, there is no disposition in matter to resist being put in motion when at rest, in other words, *vis inertiæ* does not exist The phrase has been a fertile source of error

VISION (*Videre*, to see) See *Eye, Binocular Vision, Stereoscope*

VIS MORTUA The power of pressure exerted by a body at rest, as *vis viva* is the power of a body in motion Both terms were first used by Leibnitz

VIS VIVA (*Vis*, force , *vivus*, living, from *vivo*) A measure of the kinetic energy, or inherent work of a moving body It is the product of the mass by the square of the velocity. The chief properties of the *vis viva* are the following – If a system of bodies be under the action of no external forces, the *vis viva* of the system is constant If a body move in any manner, its *vis viva* at any instant is equal to the *vis viva* of the whole mass, as if it were collected at the centre of gravity, *plus* the *vis viva* round the centre of gravity considered as a fixed point By impact of inelastic bodies *vis viva* is always lost, by explosions it is always gained , by impact of bodies which are perfectly elastic, the *vis viva* lost in compression is exactly balanced by that gained in the restitution (See *Energy* and *Mechanics*)

VITREOUS HUMOUR (*Vitrum*, glass) The transparent humour with which the greater part of the eye-ball is filled, contained in the convoluted folds of the hyaline membrane. (See *Eye*)

VOLANS Abbreviated from *Piscis Volans*, (*q v*)

VOLTAIC ARC See *Electric Light*

VOLTAIC CIRCLE, more usually called *Volta's Crown of Cups*, consists of a series of small cells of copper, zinc, and dilute sulphuric acid, joined together, the copper of one being soldered to the zinc of the next They were arranged in a circle, so as to bring the last copper near the first zinc On connecting these together by a wire, the current flows, according to our conventional phraseology, from the copper, through the wire, to the zinc

VOLTAIC ELECTRICITY Ordinary current electricity is frequently spoken of under this name, derived from that of the great inventor of the pile and battery, the first investigator in the field opened up by the observation of Galvani Voltaic electricity is treated of under various heads throughout this volume (See *Battery, Current, Electric, Pile, Volta's*, &c)

VOLTAIC PAIR Sometimes a single cell of a battery, consisting of two metals and an exciting liquid (see *Battery, Galvanic*), is called a Voltaic pair

VOLTAMETER (*μέτρον*, a measure) An instrument proposed by Faraday for measuring the strength of the electric current Its principle depends upon a law of electrolytic decomposition, viz , that the amount of decomposition that takes place is strictly proportional to the strength of the current, that is, to the quantity of electricity passing in a given time Faraday's method consists in decomposing water by means of the current, and measuring the quantity of the mixed gases given off in a certain time The ratios of the strengths of various currents *under these circumstances*, is thus obtained The construction of the voltameter is the following —It consists of a glass bottle, into the neck of which is fitted, by ground glass surfaces, a bent delivering tube Through the sides of the bottle pass platinum wires, fused into the glass, and terminated within by broad platinum plates, brought as near to each other as possible, without danger of coming in contact. The bottle is filled with acidulated water, and when the

current is passed through it, decomposition takes place, and oxygen and hydrogen are liberated at the plates When the gas is to be measured, the delivering tube is passed under water in an ordinary pneumatic trough, and a graduated vessel collects the bubbles of gas that rise from it All that is necessary then in order to ascertain the strength of the current passing is to note the time during which the action goes on, and the quantity of gas collected

VOLTA'S PILE is a form of battery used by Volta for obtaining current electricity of high tension It consists of a large number of discs of zinc, flannel, and copper, *piled* one on the top of the other in constant succession, and in that order The flannel is moistened with salt and water, or with dilute sulphuric acid, and when the first zinc and the last copper are connected by means of a wire, a powerful current is obtained The Voltaic pile is very convenient for showing electricity of high tension obtained by chemical action, since a large number of elements may be used without making the apparatus unwieldy Thus with a pile consisting of one hundred sets of plates, an ordinary gold leaf electroscope may be charged by simply putting one extremity of the pile in connection with the top plate, and the other with the earth, or the extremities may even be examined with the proof plane If the latter be applied, it is found that in an insulated pile one end is charged positively, and the other negatively, that the middle is neutral, and that the density of the electric distribution increases gradually from the middle towards the end

VOLUMETRIC ANALYSIS See *Analysis, Chemical*

VOUSSOIRS (Fr *voute*, an arch, Lat *volvere*, to turn round) The wedge-shaped stones which form an arch (See *Arch*)

VULCAN In astronomy, the name given to a planet supposed to revolve within the orbit of Mercury At present the existence of this planet is open to grave question In total eclipses of the sun it should undoubtedly be visible, unless very near conjunction, and it could hardly have been so situated during all the recent total solar eclipses

VULCANISED INDIA-RUBBER See *Caoutchouc*

VULPECULA (Lat Abbreviated from *Vulpecula et Anser*, the fox and goose) One of the constellations devised by Hevelius Within the limits of this constellation lies the remarkable nebula 27 Messier, known as the Dumb bell nebula This interesting object is one of the nebulæ which Mr Huggins has shown to be gaseous

W

WAGGON-BOILER See *Steam-Boiler*

WASAT (Arabic) The star δ of the constellation Gemini

WATCHES See *Horology*

WATER (H_2O) This liquid was considered by the ancients to be an elementary body The researches of Watt, Cavendish, and Lavoisier, towards the end of the last century, showed that it is composed of two gaseous elements—oxygen and hydrogen (See *Hydrogen*) In the pure state and at the ordinary temperature, water is transparent, free from taste and smell, and almost colourless A considerable thickness of it, is however of a bluish tint It is about 770 times denser than the atmosphere, and is the standard to which all specific gravities of solid and liquid substances are referred, the temperature in England being taken at 60° F, but on the Continent at 4° C (39 2° F) At this latter temperature water is at its greatest density, expanding whether its temperature be increased or diminished Water occurs in the solid state at temperatures below 0° C (32° F), and in the gaseous state at temperatures above 100° C (212° F), but it evaporates at all temperatures, aqueous vapour constantly being present in the atmosphere It is also supposed to exist in the solid state in minerals and salts as water of crystallisation, and it is a large constituent of the vegetable and animal kingdom, in the former constituting sometimes 90 per cent of the whole mass, and in the latter sometimes forming even a larger constituent of the body Water is almost inelastic, its specific heat is higher than that of any other substance, and it is a very bad conductor of heat, although heat is rapidly diffused throughout its mass by convection, warm water being lighter than cold water In freezing, water expands, the ice being about $\frac{1}{11}$th larger than when liquid At the boiling point, a given bulk of water is converted into 1600 times its volume of steam Pure steam is a colourless transparent gas, about half the density of atmospheric air In its liquid state water is a very important solvent and diluent, being of constant employment in chemical laboratories for these purposes, its high specific heat also renders the employment of cold water for cooling purposes, and of hot water for warming purposes, very general Water is composed of two volumes of hydrogen and one of oxygen, and it may be decomposed into these gases by a galvanic current At temperatures between 1000° and 2000° C. water is also decomposed

into its constituent gases. The metals of the alkalies and alkaline earths, when thrown into water, decompose it at the ordinary temperature, liberating hydrogen. When potassium is employed, the heat produced by the combination of the potassium and the oxygen is sufficient to cause the ignition of the liberated hydrogen. Many metals decompose water at a red heat, thus, by passing steam through a red-hot gun barrel containing iron turnings, a copious evolution of hydrogen is obtained. Under the influence of light, water is also decomposed by chlorine, forming hydrochloric acid and liberating oxygen. Perfectly pure water can only be obtained artificially by distillation; when met with in the natural state it is never pure. Rain water contains the impurities which it has contracted by passing through the atmosphere, (carbonic acid, nitric acid, ammonia, hydrocarbons, together with smoke, dust, sulphuric acid, and other constituents of the atmosphere of towns). Spring and river water is still more impure, as it contains the mineral constituents which it has dissolved from the strata with which it has come in contact. Sea water contains large quantities of common salt, together with chlorides, and sulphates of sodium, magnesium, potassium, and calcium, together with minute quantities of many other substances.

WATER, COLOUR OF. When the light transmitted by sea water is examined by the spectroscope, it is seen to be deprived of its red portion at small depths, and successively of the yellow and green at greater depths, until it appears of a violet blue. Similar results are observed in an artificial grotto in the Grindenwald glacier. This cavern is 100 metres deep, transparent in its walls, through which the solar light penetrates. The light is of a fine blue tint, the red being extremely weak, so that in the grotto human countenances assume a cadaverous aspect. On looking towards the entry, at a certain distance in the cavern, it appears to be lit up with a red light, doubtless the effect of the contrast. The thickness of the superposed mass is not enough to show a greater effect than the almost complete absence of the red, and a great diminution of the yellow. The ice is said to be 15 metres thick, but is probably less; it is perfectly compact and limpid, but with a few air bubbles.

WATER, LATENT HEAT OF. See *Latent Heat*.

WATER, MAXIMUM DENSITY OF. See *Maximum Density of Water*.

WATER OF CRYSTALLISATION. Many saline substances combine in the act of crystallising, with one or more equivalents of water, the crystalline form varying with the amount so fixed. This water is called water of crystallisation or of hydration. The number of equivalents taken up sometimes depends upon the temperature at which the operation is conducted. When this water is so loosely held as to be given off in an ordinary dry atmosphere, the compound is said to be *efflorescent*.

WATER RAM. This machine is used for raising a small quantity of water a great height by means of a water flow below. If a horizontal pipe lead from the bottom of a cistern and be closed with a cock, the pressure on the closed end is proportional to the height of the water in the cistern above that end. If the cock be opened, the water in the tube will be gradually set in motion by the column of water in the cistern, and acquire the velocity which the flow of water would have if the tube had no length, that is, if there were a simple hole in the bottom of the cistern. If now, the cock be shut, it will have to resist, not only the pressure due to difference of level, but all the momentum of the moving mass of water in the horizontal tube. This will be greater according to the length and diameter of the horizontal tube. The blow given by the moving column of water when its motion is arrested—that is, the momentum of the water—is used in the water ram as follows. A long, wide tube, slightly inclined, is supplied with water from the constant source. At the lower end of the tube is a valve which only opens outwards and upwards. Close to this, and situated in a small tube entering the main pipe, is another valve which opens downwards and inwards. The second valve has considerable weight, or is pressed down with a spring. It is also so large that when down (or open), a free flow of water can pass by it. If we suppose the wide pipe to be full of water which flows out of the large valve, this current will press upwards and close the larger valve. At this instant the whole of the water in the pipe is in motion. It is, therefore, suddenly stopped, and, by virtue of its momentum, it forces open the terminal valve through which some water is projected into the narrow pipe and up it to a level above the higher end of the wide pipe. The motion of the water being thus checked the larger valve sinks, allows more water to pass it so that the momentum of the water in the feed pipe accumulates. The same process is repeated over and over again; at each closing of the large valve a fresh quantity of water is forced out of the end valve. If this latter simply opened into a vertical pipe, the momentum of the water in this pipe would have to be overcome. To avoid this a provision called an air chamber is made. This consists of a closed vessel the top of which is full of air. The valve and exit pipe are in communication with the water in the bottom of this vessel. The air yields, by its elasticity, to the sudden influx of water into the air vessel, and when that influx has ceased and the valve closed, the compressed air forces the water up the tube.

WATERSPOUTS When whirlwinds occur over the sea, or any sheet of water, the sea is tossed into waves beneath them, and the aspect of the phenomenon suggests the belief that the water is sucked up by the whirlwind Observation, shows, however, that the water carried round by the whirlwind is not sea-water but either fresh or very slightly brackish

WATER WHEELS These familiar examples of the application of water power to machinery may be conveniently divided into two classes, namely those in which the weight of the water, and those in which the momentum of the water is mainly utilised Where the flow of water is abundant and rapid but the fall inconsiderable, the "undershot" wheel is used. The most simple form of this is a large wheel, the spokes of which are carried through the circumference and expanded into flat boards or paddles Placed vertically in running water so that the lower paddles are entirely immersed, the water will, of course, turn the wheel round when the axis is fixed It is only that paddle which is in a vertical plane, that is, at its lowest, which receives and transmits in a rotary direction the full force of the impinging water Those higher up are presented obliquely, and, therefore, virtually with less surface, to the stream A portion only of the pressure they receive is resolvable tangentially, the rest acts upon the axle of the wheel and is lost For this reason an undershot wheel is only immerged a little depth in the water Its effect is greater the wider are the paddles To avoid the loss incurred by the slipping off sideways of the water from the paddles, before it has given its full momentum to them, the driving water is usually collected in a narrow channel or trough, into which the paddles nearly fit Additional force is also gained by using curved paddles or scoops instead of flat boards, with their hollow sides presented to the stream

The overshot wheel depends mainly upon the weight of water, and is employed where only a small flow of water is available, but through a considerable height In this form of wheel scoop paddles are used The water is collected into a channel of the width of the scoops, and brought to the top of the wheel where it enters the scoops, which, acting like a series of buckets, weigh the wheel round These buckets are sometimes made moveable on horizontal axes, parallel to that of the wheel, in such a way that they remain full till they reach nearly to the bottom of the wheel, thus preserving the same weight throughout their descent If the paddles were flat, each cell or bucket would, of course, be emptied immediately after passing the horizontal position Neither undershot nor overshot wheels are found to do more than from 70 to 80 *per cent* of the theoretical amount of work The latter amount could, of course, only be obtained by the complete stoppage of the flow or fall of the water, and, though gravity would ultimately remove the water which had thus lost its moving power, yet the accumulation of the exhausted water would be inconvenient

Horizontal water wheels are occasionally used If a rectangular strip of metal be bent into the form of the letter S, and placed between two parallel discs whose diameters are equal to the height of the letter, it is clear that two curved cells will be formed If another such S shaped piece be introduced (crossing the first) with its curvature in the same sense, four such cells will be formed, and so on Water which enters such a cellular drum, at or near the axis, will reach the circumference by passing along a widening channel with curved sides As its direction tends always to be straight, it must push up against the concave side of the channel through which it passes The same takes place in all the cells, and the wheel is urged round in the same direction by each

The screw-turbine consists simply of a vertical rod around which is fastened a screw-surface like a spiral staircase, of which the well is filled up by a column This screw works in a cylinder, so that there is a spiral chamber from the top to the bottom of the cylinder Water which flows in at the top of this cylinder, is forced out of the natural or vertical direction of its descent Being compelled to flow along the screw, its tangential action upon the screw must be equal to its own lateral inertia, and accordingly the screw turns round The cylinder containing the screw is fastened into the partition between two cisterns, one above the other, so that the cylinder remains full of water

WAVE LENGTH (In Optics) According to the undulatory theory of light the wave length is the distance between the waves which cause the effect of light, from crest to crest The following are the wave lengths in parts of an inch of the undulations which produce light —

Extreme Red,	0 0000266	Blue,	0 0000196
Red,	0 0000256	Indigo,	0 0000185
Orange,	0 0000240	Violet,	0 0000174
Yellow,	0 0000227	Extreme Violet,	0 0000167
Green,	0 0000211		

(See *Undulatory Theory of Light*)

WAVE LENGTH (In Sound) In order to find the actual wave length in air for any particular note we have only to consider the rate of sound in air and the pitch of the note For let us imagine there to be two points 1100 fet apart, and let one of these points commence at the beginning of a second to give out a note consisting of say 422 vibrations per second. At the end of the second the first vibration will be at the second point B, that is 1100 feet away, the last vibration will be just starting from A, so that there will be 422 vibrations in the 1100 feet, and accordingly the distance between any two maxima of compression, that is, the wave length, will be $\frac{1100}{422}$, or 2 feet $7\frac{1}{4}$ inches nearly Similarly for notes of other pitch In general terms the length of a wave of any note is directly proportional to the time interval between two of its consecutive wave elements, or inversely proportional to the pitch of the note This law enables us to determine the velocity of sound in various media by comparing the pitch of the note produced (See *Velocity of Sound in Solids*)

WAVE LENGTHS OF THE METALLIC RAYS See *Metallic Rays, Wave Length of*

WAVES IN AIR, INSTRUMENT FOR RENDERING VISIBLE Dr Topler has devised a method of rendering visible aerial waves (*Pogg Ann* cxxvii, pp 556–580) The apparatus which he employs consists of a lamp, a beam of light from which is caused to pass through a metallic screen, and to fall upon a system of lenses of from $2\frac{1}{2}$ to 4 feet focal length, and of large diameter The screen is arranged so that it can be moved along the axis of the lens, and the latter forms an image of the hole in the screen at a distance of from 10 to 25 feet The image is received upon the objective of a small telescope, and a second screen, with a straight sharp edge, is placed at this point If the lens is perfect the entire beam of light is concentrated at the focus, and in moving the screen in front of the object glass of the telescope no change in the field of the telescope is observed until the screen reaches the luminous image, when the lens suddenly disappears (the astronomical telescope being focussed to give a sharp image of this lens) But if the lens is not perfect, if it contains a flaw, then this will refract light differently from the body of the lens, the rays from this flaw will not collect in the same focus as the other rays, when the moveable screen has nearly reached the principal image, many of the rays from this flaw (which otherwise would have reached the object glass of the telescope, and thus the eye) are now cut off, hence this flaw *appears dark on the bright ground* of the image of the lens, and when the screen is moved down so as completely to cut off the regular image of the luminous hole, many of the rays from the flaw will yet reach the objective, so that the flaw *now appears bright upon a dark ground* As the distances between the different parts of this apparatus are considerable (20 feet or more), and as the telescope may be of a high power, this method is incredibly sensitive The object to be examined must, of course, be transparent, if it is the object-glass of a telescope, this forms the principal lens, if a *flame* or the like, it is placed close to the principal lens, between it and the telescope Topler has found that perfectly homogeneous glass is exceedingly rare, it has usually either filiform flaws (which are easily detected, and but little injurious), or flaws throughout its entire mass, appearing in this apparatus as if brushed over by a brush These very injurious flaws hitherto were not discovered till the lens was almost worked out, by this apparatus they are easily detected in the glass The *flame* of a Bunsen burner shows, besides the three well known parts visible to the unaided eye, two others, an exterior large, very well defined cone (consisting of the heated products of combustion and of air), and a bright interior cone resting on the tube as the base, having a sharp outline (consisting of the mixture of gas and air before any combustion has taken place) The *electric spark* when produced by the induction coil and allowed to pass between the electrodes shows very interesting and instructive phenomena, of which, however, it would be difficult to give a clear idea in a few words The *sound wave in air* corresponding to each separate spark is, like the sound, a *single impulse*, it is beautifully visible as a *bright circle* or *ellipse* around the source of sound, moving regularly from the centre outwards A succession of sparks in regular intervals, gives moving circles of light The spark from a Leyden jar gives a sharp sound, and one increasing circle of light, one sound wave That this is a sound wave Topler proved by trying in vain to blow it aside by a feeble current of air, and also by finding it progress more rapidly in heated air But more interesting yet is his experiment on the reflected sound-wave Suspending a glass plate from the brass electrodes by means of corks, he saw in lines of light precisely the same phenomenon which we observed when circular waves of a liquid meet a plane wall, they are reflected as circles described from a point as far behind the obstacle as the origin of the wave is in front of the same By placing the electrodes either in the axis of the apparatus or at right angles to it Topler found that in the first case the lines were elliptical, in the latter circular, so that the wave is a surface of revolution around the electrodes as an axis It may well be said that by means of Topler's apparatus we *see the sound*, in Chladni's and even in Kundt's experiments we only see the motion imparted by air to some other body, not the motion of the air itself For the application of this method to the microscope see Topler's article in *Pogg. Ann.*, also *Silliman's Journal*, vol. xliii., p. 390.

WAVES IN LIQUIDS. If the circular end of a solid cylinder be placed on the surface of a liquid at rest, and then suddenly depressed, the depression of the water beneath the cylinder will not cause an immediate, general, and uniform lifting of the whole of the rest of the water's surface; but the water will be raised in the neighbourhood of the liquid in the form of a circular elevation or wave, which travels in an expanding circle, of which the cylinder is the centre. Similarly, if a cylinder be immersed in a vessel of water at rest, and then raised, the cylinder's place will be immediately occupied by the neighbouring water, which will thereby form a circular valley around the cylinder, and this valley will travel in a widening ring in the same manner as the wave of elevation in the former case. When, therefore, the cylinder is raised and depressed at regular intervals, a succession of such circular waves of elevation and depression will succeed one another, and a series of waves will be formed. The waves in this case diminish in intensity as they recede from the central source. If the liquid be confined in a straight trough, the diminution by radiation is prevented, and the only decrease in the wave's intensity (height) as it travels is due to friction. Such a straight rectangular trough is convenient for studying the phenomena of waves if its sides are of glass. If we imagine a wave of elevation, followed by a wave of depression, to travel from left to right, a particle of the liquid surface will perform a complete circle in the direction of the hands of a watch as the complete double wave passes by, the upper half of the circle being completed during the passage of the elevation, and the lower half during that of depression. The particle will be at its original level for a moment when the first half (of the double wave) has passed by. The height of the wave from the bottom of the valley to the top of the hill is the diameter of the circle performed by such a particle, and a line joining the centres of all such circles in the original surface of the liquid. If we examine other points of the surface of the liquid, we find that, while one particle has performed a complete circle, the wave has progressed; that is, some of the neighbouring particles to the right have performed parts of their circular paths, more or less complete according as the distance from the first particle is less or greater. The particles are said to be in different "phases" of motion. The length of the wave is usually considered as the distance from summit to summit of neighbouring waves, or from valley to valley. The height of a wave is reckoned from top of the hill to bottom of the valley. This is clearly the diameter of the circular path described by a particle, and is called the amplitude of the particle's motion, or amplitude of the undulation. That particle which is a whole wave length, in the direction of the wave's progression, from the particle which has come to its original position, is just commencing to rise and advance; that one at half a wave's length has performed the upper half of its circular path, and is on the same level as it was to begin with, but advanced to the right a distance equal to half the wave height, and so on. In such a series of waves we have supposed the motion to be symmetrical – that is, the particles move in circles. This is not always the case. Indeed, most frequently the particles move in ellipses, whose major axes are horizontal or vertical, according as the wave length is greater or less in proportion to the amplitude, than it is in the case of circular motion. In all cases where closed curves are described, the water does not advance with the wave permanently—that is, a body floating on the water will not drift. But when the water is urged into motion by a violent impulse, as by a high wind, the paths of the particles are not closed, and the floating body will drift.

WATT'S PARALLEL MOTION. See *Parallel Motion.*

WAX. A name applied to a great many substances of similar properties, of which bees wax may be taken as the type. This is a yellow, tough, solid substance, insoluble in water, softening with heat, and becoming liquid below the boiling point of water. It may be bleached by exposure to the atmosphere in thin shreds. It is a mixture of several neutral bodies and fatty acids.

WEATHER. The condition of the atmosphere at any place, as respects humidity, temperature, motion, electricity, &c. (See *Atmosphere*, *Climate*, *Cloud*, *Dew*, *Fog*, *Snow*, *Hail*, *Winds*, *Hygrometer*, &c.)

WEATHER-GLASS. The weather-glass consists of a syphon barometer (which see), upon the mercury of whose shorter limb floats a plug of glass. This plug is partly counterpoised by a smaller weight, which is connected with the floating plug by a silk thread passing over an easily moved wheel. The axis of the wheel bears an index, which moves over a circular face. When the atmospheric pressure increases, the height of the mercurial column in the closed end is raised; the mercury in the shorter open end sinks, and, consequently, the heavy weight which floats upon it sinks and lifts the lighter weight at the other end of the string, turning, as it does so, the wheel round which the string is wound, and thereby moving the index. When the atmospheric pressure diminishes, the supported column is less, and therefore more mercury enters the open end, floating up the heavier glass weight, and therefore moving the wheel and index in the opposite direction. As air charged with aqueous vapour is lighter than dry air (see *Weight of Gases*), a fall in the barometer often indicates a partial saturation of the air with

water, a state of things which, of course, frequently precedes a condensation of watery vapour—that is, rain When a mass of air is moving with great velocity in the neighbourhood of the barometer, the surrounding air seeks to supply the place of the moving air, and therefore becomes less dense As such rapidly-moving aerial currents are usually accompanied by storms, one may regard the sudden "fall" of the barometer as a precursor of rain or of other violent atmospheric disturbance, and hence its use as a "weather glass"

WEATHER-PREDICTION In all ages men have endeavoured to elucidate the laws influencing weather changes, and to deduce rules by which to predict such changes The attempt hitherto has not been very successful, except in so far as the anticipation of the progress of well-marked storms already in progress is concerned (See *Storm Warnings*)

The popular weather-tokens are for the most part founded on real laws of atmospheric change, but scarcely any of them afford, strictly speaking, more than an argument from probability Perhaps the evidence derived from the motions of the cirrus clouds is that which, if rightly studied, would enable us to anticipate most satisfactorily the future condition of the weather, because in many instances the motions in the upper region of the air indicate those which will presently prevail in the lower For the [illegible]ation of ordinary weather prognostics, the reader is referred to Sir Humph[illegible]

The teachings of the *barometer*, *hygrometer*, and *thermometer*, as to the condition of the air, studied with careful reference to the past progress of weather changes, to the present aspect of the sky, the direction of the wind, and the like, undoubtedly afford, in many instances, very sure means of anticipating approaching weather changes But much careful study of the subject is still necessary before sound and general laws can be established

The influence of the moon on the weather has been much debated, and while the ordinary rules associating the lunar phases with weather variations have been shown to be altogether untenable, it has yet not been thought wholly impossible that the moon should exert other influences, as in dispersing clouds, &c Sir John Herschel and Arago have, indeed, assigned to the moon an influence of this sort, and Mr Park Harrison, from a careful study of the Greenwich meteorological records, has shown that there is at Greenwich an appreciable tendency to cloud dispersion shortly after full moon Schübler, after sixteen years observation, has found that winds from the south and west increase in frequency during the moon's first quarter, while winds from the north and east are at a minimum during the moon's last quarter But these influences are too local in their character to be regarded as demonstrating the moon's influence Mr Baxendell, of Manchester finds from the Petersburg observations, that changes take place at St Petersburg precisely opposite in character to those noticed by Mr Harrison in the Greenwich records

WEIGHT OF GASES It is found (see *Elasticity of Gases*) that the volume of a mass of any gas varies almost exactly in the inverse ratio of the pressure to which it is subjected Also, that all gases expand very nearly exactly the same fraction of their volumes for equal increases of temperature (See *Heat*, *Expansion of Gases*) It follows that comparison between the relative densities of various gases can be made at any temperature and pressure, since all are affected alike The actual weight of a given volume of a gas having been ascertained at a given pressure and temperature, the weight of the same volume or the volume of the same weight at any other pressure or temperature can be calculated, and, for the sake of uniform comparison, the constant temperature 32° F and 30 inches barometric pressure are usually taken The weight of a gas in comparison with hydrogen, if equal volumes of them are taken, or the specific gravity of gases, is at once known if we know the atomic weight of the elements of which the gas is composed, the number of atoms concerned in the composition of the gas, and the contraction which the constituents undergo in combining together Thus the atomic weight of oxygen (in comparison with hydrogen), is 16 Water is formed when two volumes of hydrogen unite with one volume of oxygen And the three volumes of the mixture contract in uniting to two volumes, therefore two volumes of vapour of water or steam weigh 18 times as much as a volume of hydrogen, or one volume of steam weighs 9 times as much, the specific gravity of steam is therefore 9 Again, equal volumes of chlorine and hydrogen unite, without contraction, to form hydrochloric acid The atomic weight of chlorine is 35 5 Therefore 36 5 is the weight of two volumes of hydrochloric acid, or the specific gravity of hydrochloric acid is 16 25 The specific gravities of simple gases are, of course, their atomic weights. In order to obtain the specific gravity of gases referred to air, we have to divide their specific gravities, in regard to hydrogen, by the specific gravity of air, which is 14 5

WEIGHT THERMOMETER This instrument was used by Dulong and Petit in many of their investigations It consists of a glass flask, capable of holding about half-a-pound of mercury, the neck of which is a capillary tube three or four inches long, bent generally twice at right angles The glass vessel is accurately weighed, and then completely filled with mercury at 0° C, and weighed again. Thus the weight of mercury contained in it is known. If the

instrument be now exposed to a warm temperature, the glass and the mercury both expand, but the mercury expands by a much greater amount than the glass, and a portion of it is driven out of the capillary tube and is collected in a capsule arranged for the purpose The weight of the mercury expelled is then determined The amount expelled is simply proportional to the number of degrees of temperature through which the vessel has been raised, on the supposition that mercury expands uniformly in glass, and it depends upon the difference between the rates of expansion for mercury and glass, and having once determined the coefficient of apparent expansion for mercury enclosed in the particular glass employed, it is easy to calculate the temperature to which the thermometer has been raised

WEIGHTS, ATOMIC, OF ELEMENTS

Aluminium,	27 34	Molybdenum,	96 00
Antimony,	122 00	Nickel,	59 00
Arsenic,	75 00	Niobium,	94 00
Barium,	137 00	Nitrogen,	14 00
Bismuth,	210 34	Osmium,	199 00
Boron,	10 90	Oxygen,	16 00
Bromine,	80 00	Palladium,	106 50
Cadmium,	112 24	Phosphorus,	31 00
Cæsium,	133 00	Platinum,	197 10
Calcium,	40 00	Potassium,	39 10
Carbon,	12 00	Rhodium,	104 30
Cerium,	92 00	Rubidium,	85 30
Chlorine,	35 50	Ruthenium,	104 20
Chromium,	52 48	Selenium,	79 50
Cobalt,	58 74	Silicon,	28 00
Copper,	63 50	Silver,	108 00
Didymium,	96 00	Sodium,	23 00
Erbium,	114 60	Strontium,	87 50
Fluorine,	19 00	Sulphur,	32 00
Glucinum,	9 30	Tantalum,	182 00
Gold,	196 66	Tellurium,	129 00
Hydrogen,	1 00	Thallium,	203 00
Indium,	72 00	Thorinum,	238 00
Iodine,	126 82	Tin,	118 00
Iridium,	197 00	Titanium,	50 00
Iron,	56 12	Tungsten,	184 00
Lanthanum,	92 00	Uranium,	120 00
Lead,	206 91	Vanadium,	51 30
Lithium,	7 00	Yttrium,	61 70
Magnesium,	24 32	Zinc,	65 00
Manganese,	55 00	Zirconium,	89 50
Mercury,	200 00		

WEIGHTS See *Metric System*

WENHAM'S PRISM A glass prism of a peculiar form which is placed immediately over the object glass of a compound microscope, so as to divide the bundle of rays coming through it into two halves, one of which is allowed to proceed as usual along the main body of the microscope, whilst the other half is reflected obliquely along the axis of the secondary body This arrangement is now usually adopted to obtain a stereoscopic effect in the compound microscope. (See *Binocular Microscope*)

WHEATSTONE'S BRIDGE See *Bridge, Wheatstone's*

WHEEL AND AXLE A modification of the lever, consisting of two cylinders of different radius having a common axis, the smaller being termed the axle, and the larger the wheel A cord is wound round the wheel in one direction, and another cord round the axle in the opposite direction The weight is attached to the latter, and the power is applied to the former When both the power and the weight are vertical, and we consider the machine as seen in the direction of the axis, we have two parallel forces acting at the extremities of two arms of a lever whose fulcrum is in the axis The condition of equilibrium is, therefore, that the power multiplied by the radius of the wheel shall be equal to the weight multiplied by the radius of the axle

WHEEL BAROMETER See *Barometer*.

WHIRLWINDS See *Winds*

WHITE CAST IRON. See *Iron, Cast.*

WHITE LEAD See *Carbon, Carbonate of Lead*
WHITE LIGHT, RECOMPOSITION OF See *Recomposition of White Light*
WHITE PRECIPITATE See *Mercury, Chlorides*
WHITE'S PARALLEL MOTION See *Parallel Motion.*
WHITE VITRIOL See *Sulphates, Zinc*
WILLOW LEAVES, SOLAR See *Sun*

WINCH A modification of the wheel and axle, the power being applied by means of a rectangular lever or cranked handle It is used for drawing water from wells, for turning wheels, lifting weights, and for a variety of common purposes Steam winches are much used for lifting cargoes from the holds of vessels

WINDLASS (The origin of the latter part of the word is doubtful It was formerly spelt windlace, and this points to wind (verb), and lace (noun), as the component words The Dutch equivalent, however, is *windas*, from *winden*, to wind, and *as*, an axis) An application of the wheel and axle It usually consists of a horizontal axle supported on props, so as to be capable of revolution about its central line, and a winch the arm of which represents the radius of the wheel One end of a rope or chain is attached to the axle, and the other end to the weight, thus, by turning the winch, the rope is coiled on the axle, and the weight is raised The windlass used in ships for raising the anchors consists of a strong beam of wood placed horizontally, and supported at its ends by iron spindles The beam is pierced with holes directed towards its centre, in which long levers or handspikes are inserted for turning it round when the anchor is to be raised

WINDS The movement of the air in currents from one place to another

Speaking generally, all winds are caused by the variations taking place continually in the condition of the air as respects heat and moisture, and therefore as respects rarity When the air over a given place becomes rarefied, that is, when the atmospheric pressure there becomes relatively small, that region at once becomes a centre towards which inflowing air currents direct themselves According to the nature, extent, and continuance of this diminution of pressure, the nature of the resulting air currents varies within very wide limits

Taking first a relation affecting the earth as a whole, we have in the excess of heat at the earth's equatorial regions the cause of the permanent or quasi permanent winds called the trades and the counter trades The air at the equator becomes rare through the great heat continually poured upon this part of the earth's surface Thus there is a continual indraught towards this region of excessive heat This indraught cannot be supposed to come from polar regions, but rather from the temperate and sub tropical regions which lie nearest to the region of greatest heat If the earth were not rotating, the air thus flowing towards the equator would simply travel southwards in the northern hemisphere, and northwards in the southern But as the earth is rotating, and these air currents are flowing from latitudes where the motion of rotation is less to latitudes where this motion is greater, the air seems to lag against the direction of the earth's motion, or to come from the east, (since the earth's rotation is towards the east) This lag, combined with the motion towards the equator, causes these winds to be north easterly in the northern hemisphere and south easterly in the southern

Such are the trade winds, though it must be carefully borne in mind that these winds are by no means in reality permanent Captain Maury points out that they are often replaced, even in the so-called *trade latitudes*, by winds blowing in a contrary direction

Since there is this tendency to the prevalence of winds towards the equator, it follows necessarily that the air above equatorial regions must be, for the most part, passing away towards higher latitudes, and for a reason precisely similar to that which causes winds blowing towards the equator to lag towards the west, winds blowing from the equator would appear to hasten (in advance of the earth's rotation, that is) towards the east Thus, then, we have ordinarily in the regions of air above the trade winds south-westerly winds in the northern, and north-easterly winds in the southern hemisphere

In the temperate and arctic regions we do not find so marked a tendency towards the existence of permanent winds as in tropical and sub tropical regions Yet, on the whole, there is a tendency to the prevalence of south-westerly winds north of a region of frequent calms, which marks the northern limit of the trades, while south of a similar southern region of calms there is a tendency to the prevalence of north westerly winds

Next to the trades and counter-trades in importance, and in their tendency to permanence, we must reckon land and sea breezes The origin and nature of these are easily explained. The temperature of the sea varies much less during the day than the temperature of the land. Thus, during the heat of the day the sea is cooler than the land, at night the sea is warmer than the land Hence, in the day time, the air flows in from the sea to supply the place of the air which rises from above the heated land, while at night the heavier air over the cooled land

flows towards the sea When the land is hottest, the sea breeze flows with greatest force, the land breeze attains its greatest force during the coldest part of the night

Monsoon winds, which may be regarded as a modified form of trade wind, have been alrea dealt with (See *Monsoons*) Other winds also, depending on the existence of such regions the Sahara desert, &c, have been described under the heads *Etesian Winds, Samiel, Sirocco,* &

Hurricanes or cyclones, called also tornadoes, typhoons, &c, originate in causes operati suddenly and effectively over a wide extent of country, but once started, these storms indica in their progress the operation of cosmical causes It would seem that all true cyclones hav their origin in sub-equatorial regions, but not at the equator itself Nor, again, has any hurr cane been known to cross the equator, though it has happened that two have raged at same time on opposite sides of the equator, and in the same longitude Commencing with inrush of air from all sides towards a central region of rarefaction, it is easily seen tha rotatory motion must needs be communicated to the resulting atmospheric disturbance Fo we consider a definite region in the northern hemisphere towards which air is rushing fro sides, we see that the air coming from the north would be deflected towards the west be reaching the centre of disturbance, while the air coming from the south would be deflected wards the east And all the air-currents with northing would exhibit a westerly displacem of greater or less extent, while all the air currents with southing would exhibit an easte deflection Thus the region of air would be moved by westerly forces in its northern half, and b easterly forces in its southern half, and so would exhibit a rotation opposite to that of the hands of a watch placed face upwards on a map of the region And throughout the progress of a hurricane in northern latitudes, this form of rotation is exhibited On the other hand, in southern latitudes the rotation is in the reverse direction

Cyclones, besides that whirling motion which constitutes their characteristic peculiarity, exhibit also a motion of translation, sometimes very rapid, which carries them from the equator first westwards, and afterwards eastwards, along paths corresponding closely with the course of the principal oceanic currents

Cyclones vary in size from 50 to 500 or 600, or even 1000 miles in diameter, and travel a rate varying from 9½ to 45 miles per hour, but the velocity of the whirling motion is often greater

(See further Dové *on the Distribution of Heat,* and on the *Laws of Storms*, Maury's *Physic Geography of the Sea*, the third volume of Taylor's *Scientific Memoirs*, Espy's *Philosophy of Storms*, &c

WINNECKE'S COMET See *Comet*

WINTER See *Seasons*

WINTER CLIMATE See *Isocheimenal, Isothermal, Climate,* &c

WITHERITE See *Carbon*, *Carbonate of Barium*

WOLFRAM See *Tungsten*

WOODBURY TYPE See *Photographic Engraving*

WOOD TIN See *Tin*

WORK A force is said to do *work* when it moves the body to which it is applied, and the work is measured by the product of the resistance overcome into the space through which it is overcome The amount of work done in raising a weight does not depend only on the weight, but also on the space through which it is lifted (See *Foot-pound*) When work is done by means of a machine, the work done at the one extremity is exactly equal to that applied at the other, passive resistances such as friction being neglected Thus, if we consider a lever with arms 4 ft and 1 ft respectively, we find that a power of 1 lb will support a weight of 4 lbs, but if the weight be raised 1 ft, the power must descend through 4 ft, so that the work done at the two extremities of the lever is the same If a force always acts in a direction perpendicular to the direction of motion, it does no work, thus the pressure of the horizontal plane on which a stone is rolling, the tension of a cord to which a pendulum bob is attached, the attraction of the sun on a body describing a circle about the sun as centre, are all examples of forces which do no work (See *Energy*, and *Machine*)

WORK OF THE BODY See *Muscular Power*

WROUGHT IRON. See *Iron, Malleable*

X

XANTHIN A name applied to some yellow colouring matters of vegetable origin. Frémy and Cloez called the insoluble yellow colouring matter of flowers by this name, whilst Schunck and Higgin used it to designate a yellow substance from madder

XANTHINE or XANTHIC OXIDE. An organic body found in urinary concretions, and

ared in many ways from animal substances Its formula is $C_5H_4N_4O_2$ It is a white substance almost insoluble in water and forming crystallisable compounds with both acids and es

XYLENE or XYLOL, a hydrocarbon homologous with benzol and toluol Formula H_{10} It is a colourless liquid of a faint tarry odour, boiling at 139° C, specific gravity 0 86 lidine ($C_8H_{11}N$), is the artificial alkaloid, homologous with aniline, prepared from xylol by a milar series of reactions to those employed in the preparation of aniline from benzol

Y

YEAR (Sanscrit *yra*, to surround) The period occupied by the earth in completing one uit of her orbit According as the circuit is considered with reference to different features ho orbit the length of the year varies Thus there are the following different orders of r —

The Sidereal Year This is the mean interval occupied by the earth in so completing a cuit that the radial line from the sun to the earth points to exactly the same part of the estial sphere at the end as at the beginning of the circuit Its length is 365d 6h 9m 9 6s

2 *The Tropical Year*, is the mean interval separating the successive passages by the earth of the equinoctial point of her orbit As this point is continually retrograding (see *Precession of Equinoxes*), the tropical year is less than the sidereal year It is to be noticed that if the tropical year were measured from the autumnal equinox or from either solstice, its length would not be precisely the same as when it is measured from the vernal equinox, because of the varying velocity of the earth in her orbit The tropical year contains 365 d 5 h 48 m 48 6 s

3 The *Anomalistic Year* is the interval separating successive passages by the earth of the perihelion of her orbit As the perihelion is continually advancing, the anomalistic year is slightly longer than the sidereal year, its mean length is 365d 6h 13m 49 3s

The *Civil Year* is the year of the *Calendar*, (*q v*)

The *Julian Year* is the year of the Julian calendar, or 365¼ days

The *Lunar Year* is a period of 12 lunar months, or 354 days It is still used by Jews and Mohammedans

YTTRIUM A rare metallic element, the basis of the earth Yttria, and associated with Erbium and Terbium (which see) Atomic weight 61 7 Symbol Y Its compounds are unimportant

Z

ZAFFRE The commercial name given to an impure oxide of cobalt containing silica. It is used as a blue colouring agent for pottery purposes

ZAURAC (Arabic) The star γ of the constellation Eridanus

ZAVIJAVA (Arabic) The star β of the constellation Virgo

ZENITH (Arabic) The point immediately overhead

ZENITH DISTANCE The distance of a star from the zenith, or the complement of its *altitude*, (*q v*)

ZENITH SECTOR An instrument of great importance in astronomical observation It is constructed for the observation of stars which pass close to the zenith, and measures their nearest approach to that point At this time the place of such stars is not appreciably affected by refraction

ZERO, ABSOLUTE See *Absolute Zero of Temperature*

ZINC A metallic element of a bluish white colour, somewhat brittle and crystalline, but malleable when hot, and tolerably permanent in the air Specific gravity between 6 9 and 7 2, it melts at 412° C (773° F) and boils at a full red heat, burning in the air with a brilliant flame Atomic weight 65 Symbol Zn Owing to its permanence in the air it is much used for slight building erections, both alone and as a protecting coating for iron, under the name of galvanized iron Zinc dissolves easily in acids with evolution of hydrogen, and is largely used for scientific purposes, as the positive element of galvanic batteries, and for preparing hydrogen Zinc forms one oxide (ZnO) which is a white insoluble powder uniting with acids to form zinc salts (see the respective acids), it is prepared on the large scale for use as a pigment under the name of zinc white, and is superior to white lead in not blackening with sulphuretted hydrogen, and in being non-poisonous.

ZINC GLASS See *Silicates, Silicate of Zinc.*

ZINC VITRIOL. See *Sulphates, Zinc*.
ZINC WHITE. See *Zinc*.
ZIRCONIA LIGHT. See *Lime Light*.
ZIRCONIUM. The metallic basis of the rare earth zirconia. Atomic weight 89·6. Symbol Zr. *Zirconia* (ZrO_2), is a hard white powder much resembling silica. When ignited in the oxy-hydrogen blow pipe, zirconia emits an intensely brilliant light, and, owing to its non-volatility zirconia cylinders are now used instead of lime in the lime light. The silicate of Zirconia (ZrO_2SiO_2), is the precious stone *Zircon, Jargon, or Hyacinth*.

ZODIAC (ζωδιακός, from ζώδιον, dim of ζῷον, an animal.) An imaginary belt on the heavens centrally divided by the ecliptic on either side of which it extends to a distance of 9 degrees. It is divided into twelve *signs*, called in order Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricornus, Aquarius, and Pisces. (See these severally.) Much discussion has taken place respecting the origin of the zodiacal signs and the epoch of their invention; but the subject has never rewarded its investigators with any result worth a tithe of the pains they have taken. See Dupuis, *Mémoire sur l'Origine du Zodiaque*; Bailly, *Histoire de l'Astronomie Ancienne*.

ZODIACAL LIGHT. In astronomy a faint light of a lenticular shape, seen along the zodiac near the place of the sun shortly after sunset and before sunrise. It is inclined eight or nine degrees to the ecliptic, and some astronomers consider that its mean plane is that of the sun's equator.

It has been shown by Laplace that the zodiacal light cannot be a solar atmosphere. No solar atmosphere could extend farther than one third of the way towards the orbit of Mercury, whereas the zodiacal light extends farther than the orbit of Venus, if not beyond the orbit of the earth.

The hypothesis usually adopted is that which regards the zodiacal light as consisting of multitudes of minute bodies travelling around the sun. Though separately invisible these bodies would be collectively visible just as the Milky Way can be seen, though not its component stars. But the hypothesis according to which the zodiacal light is regarded as due to bodies travelling in nearly circular orbits around the sun can hardly be admitted in the face of what we now know respecting the actual motions of the meteoric systems. (See *Meteors, Luminous*.) Remembering that the orbits in which these systems revolve are for the most part very eccentric, and extend into space far beyond the orbits of Saturn and Jupiter, we must explain the permanence of the zodiacal light as due to a permanence in the general condition of that portion of space the light belongs to, not to a permanence in the actual constitution of the systems from which the light comes. Doubtless the meteors which at any one time supply the light, pass far away presently into space. But as their place is supplied by others the zodiacal light remains. However, it cannot but be seen that this explanation involves the recognition of the possibility that at times noteworthy changes may take place in the appearance of the zodiacal light. This accordingly has been found to be the case.

The zodiacal light has sometimes been seen on both sides of the heavens, and even for complete arch from the eastern to the western horizon. This corresponds with the expl we have here given, since at times the region of space outside the earth's bit migl thickly peopled with meteoric bodies (and we know it is always more or less densely s with them), as to send light even from those parts of the heavens whence usually only su planets in opposition reflect light to us.

ZODIACAL LIGHT, SPECTRUM OF. The spectrum of this light has been obser by Angstrom, who found it to be almost monochromatic, exhibiting a single brilliant band supposes it to be identical with the spectrum of the *Aurora Borealis* (which see).
ZOETROPE. See *Persistence of Vision* and *Phenakistoscope*.
ZOSMA (Arabic.) The star δ of the constellation Leo.
ZUBEN EL CHAMALI (Arabic.) The star β of the constellation Libra.
ZUBEN EL GENUBI (Arabic.) The star α of the constellation Libra.
ZUBEN EL HAKRABI (Arabic.) The star γ of the constellation Libra.

THE END.

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